

Harmonizing Global Metrics for Data Center Energy Efficiency

データセンタのエネルギー効率に関する指標の世界協調について

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

February 28th, 2011

世界的タスクフォースは、PUEの測定方法について合意に達するとともに、追加的なエネルギー効率指標に関する議論を継続する
2011年2月28日

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.

【仮訳】 21世紀において、データセンタは事業運営において非常に重要な役割を担うものとなった。需要が増加しエネルギー価格が上昇するなかで、重要な役割を担うこれらの設備の所有者や管理者にとって、エネルギー効率指標を利用して設備の性能を評価し向上させることは必要不可欠である。しかしながら、多数の世界的企業が存在するにもかかわらず、多くの場合、これらの指標は世界レベルでは一貫した形で利用されていない。

この一貫性がない状況に対して、データセンタ業界における世界的なリーダーが、主要なエネルギー効率指標を測定する手法の基準と報告方法の合意を目指して、チームを作り定期的に会議を開催してきた。参加組織は、米国エネルギー庁の「セーブ・エネルギー・ナウ」と「連邦エネルギー管理プログラム」、米国環境保護庁の「エネルギースター・プログラム」、欧州委員会共同研究センターの「データセンター・コードオブコンダクト（行動規範）」、日本の経済産業省とグリーンIT推進協議会、そしてグリーングリッドである。

2010年2月の合同声明は、目標と協同のための基本理念を強調している。この1年間、このチームは、詳細な測定ガイドラインを提供するとともに、より優れたITのエネルギー生産性指標を業界へ導入するための材料を提供する場として活動してきた。本文書は、2011年2月28日時点で達している合意を反映するものである。このチームは、データセンタのエネルギー効率の向上と温室効果ガス排出係数の改善に向けた継続的な取り組みに対し、今後も協調を続ける予定である。

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

【仮訳】 目標

データセンタのエネルギー効率を世界規模で改善するため、これまでの世界規模の経験と取り組みを共有し、各参加機関が公式に承認し導入することができる指標と測定基準を確立することを目標とする。特に、以下の具体的な目標を含むこととする：

1. 初期段階の指標の確認
2. 各指標の定義
3. 各指標の測定プロセスの定義
4. 追加指標の開発に向けた意見交換の場を設置

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.

【仮訳】期待される成果

タスクフォースの活動では、以下のような成果をめざす：

成果(1) - 実際のエネルギー消費量に対する実際のデータセンタのIT機器の仕事量を測定する、効果的なエネルギー効率指標。IT機器の仕事量を定義する際、以下の中間測定方法が定義され、かつまたは有効である。

成果(1.a) - IT機器について：IT機器の定格エネルギー消費量に対する仕事能力を測定する。また、IT機器利用率を測定する。

成果(1.b) - データセンタの設備とインフラについて：データセンタのインフラの効率（PUE = Power Usage Effectiveness）を測定する。

成果2 - 炭素排出量削減のため、再生可能エネルギーと再利用エネルギーの量を測定する。

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.

【仮訳】ガイドライン

成果(1.a)と(1.b),そして(2)に取り組むための指標の開発においては、先に述べた期待される成果の全ての側面に対応するために、全体的な枠組みが形成されることが望ましい。

タスクフォースは以下のように議論をまとめ合意に達した：

成果 (1. b) – 次のような原則によるPUEを測定することが推奨される

- ソースエネルギーを用いたPUEが、エネルギー効率を測る指標として望ましい。なお、PUEはデータセンタの全消費エネルギーをIT機器の消費エネルギーで割ったものである。
- 最終的にIT機器（サーバ、ストレージ、ネットワーク等）の負荷の直接測定を可能にするため、業界はIT機器のエネルギー測定能力を改善すべきである。IT機器の消費エネルギーの測定をPDUの出力にて実施することが推奨される。少なくとも、IT機器の消費エネルギーの測定はUPSの出力にて行うべきである。
- データセンタにおいては、全消費エネルギーの測定はutility handoff（ユーティリティの責任転換箇所；施設と外部の境界）における全エネルギー源を含めて行うべきである。全消費エネルギーは、IT機器の消費エネルギーに加え空調や照明、他のインフラの消費エネルギーを含むべきである。
- 測定ガイドラインに関する付加的な詳細が、下記のPUE測定に関する Appendix A に付け加えられている。この付加的な詳細は、異なる種類のエネルギー（再生可能なエネルギーを含む）の利用やオンサイト発電、エネルギーの再利用など、多様な事例におけるPUEの公平な測定方法に関して、具体的なガイドラインを提供する。

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.

【仮訳】 タスクフォースは、期待される成果に向けた中間段階として以下のコンセプトについて合意した。

成果 (1.a) - 期待される成果に記載されているように、この分野の指標はIT機器の潜在的な能力と利用効率の両方に対処する必要がある。

成果 (2) - 期待される成果に記載されているように、この分野の指標はオンサイト発電（再生可能なエネルギーを含む）、エネルギーの再利用とデータセンタ施設での炭素排出に対処する必要がある。

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

【仮訳】これまでの進展と今後の展開

タスクフォースが検討中の全体的な枠組みに関して、いくつかのアプローチが評価されつつある：

- データセンタの総合的な効率性を評価する指標（代表的なアプローチはDPPE:
http://www.greenit-pc.jp/topics/release/pdf/dppe_e_20100315.pdf)
- データセンタの総合的な効率性を評価する多重パラメーターの枠組み（代表的なアプローチはグリーングリッド生産性指標：<http://www.thegreengrid.org/en/Global/Content/white-papers/TGG-Productivity-Indicator>)

提案された場合、他の枠組みも検討される。

期待される成果に関して：

成果 (1) - 実際のエネルギー消費量と比較した、実際のデータセンタのIT機器の仕事量を測定する。現時点ではタスクフォースは主として成果 (1.a) に集中している。

成果 (1.a) - IT機器について： IT機器の定格エネルギー消費量に対する定格仕事能力を測定する。また、IT機器利用率も測定する。過去1年の間、タスクフォースは以下の指標を検討し、業界での試行を通じてそれらの指標の適用性に対する評価を続けている。

- IT機器エネルギー効率 (IT Equipment Efficiency, ITEE) とIT機器利用率 (IT Equipment Usage, ITEU)。詳細はGIPCによる資料を参照：http://www.greenit-pc.jp/topics/release/pdf/dppe_e_20100315.pdf
- データセンターエネルギー生産性 (Data Center Energy Productivity, DCeP) プロキシ、Bits per kWh プロキシ、CPU稼働率 (CPU Utilization) プロキシ、OS instance プロキシ。詳細はグリーングリッドによる資料を参照：<http://www.thegreengrid.org/en/Global/Content/white-papers/Productivity%20Proxy%20Proposals%20Feedback%20Interim%20Results>

成果 (1.b) - データセンタの設備とインフラについて： データセンタのインフラの効率 (PUE) を測定する。上記の改定ガイドラインを作成した結果、PUEに関する顕著な論点は現在のところ存在しない。

成果 (2) - 炭素排出量削減のため、再生可能エネルギーとエネルギーの再利用量を測定する。過去1年の間、タスクフォースは以下の指標の評価を開始した。この分野のガイドラインを提供するための更なる研究が必要である。タスクフォースは、新しい指標に向けた研究を進めており、現時点では以下の指標に対する評価が実施されている：

- エネルギー再利用の有効性 (Energy Reuse Effectiveness, ERE)。更なる詳細はグリーングリッドによる資料を参照：<http://www.thegreengrid.org/en/Global/Content/white-papers/ERE>

- 炭素利用に有効性(Carbon Usage Effectiveness, CUE) 。更なる詳細はグリーングリッドによる資料を参照：http://www.thegreengrid.org/en/Global/Content/white-papers/Carbon_Usage_Effectiveness_White_Paper
- オンサイト発電の有効性 (On-site Energy Generation Efficiency, OGE) とエネルギー炭素強度 (Energy Carbon Intensity, ECI) 。更なる詳細はGIPCによる資料を参照：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.

【仮訳】

これは、タスクフォースの期待する成果に関する状況を更新し、エネルギー効率指標の共通認識を推進するためのガイダンスである。本ガイダンスは、エネルギー消費と運用効率における効果を最大にするために、継続的な議論と様々な利害関係者からの追加インプットによりさらに整備、拡充される。最低限の推奨からベストプラクティスまで幅の広いガイダンスを実施しながら世界的に受け入れられる指標や測定基準の整備を進めるということに、参加各機関は極めて高い関心を持って取り組んでいる。

タスクフォースはアメリカ、イタリア、日本にて会議を開催し、最近活動の開始から2年の節目を迎えた。タスクフォースは今後もデータセンタのエネルギー効率に関する世界指標の協調に向けて、指標に関する議論と協同を続けることを確認した。

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.

参加機関

本会議に参加した全ての機関によってタスクフォースが構成されており、このグループは状況を進展させるために定期的に会議を開催している。各機関からの全ての参加者は、進捗に応じてグループが適当だと判断した時期に6ヶ月から12ヶ月毎に顔を合わせ、会議の開催を継続する。

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.

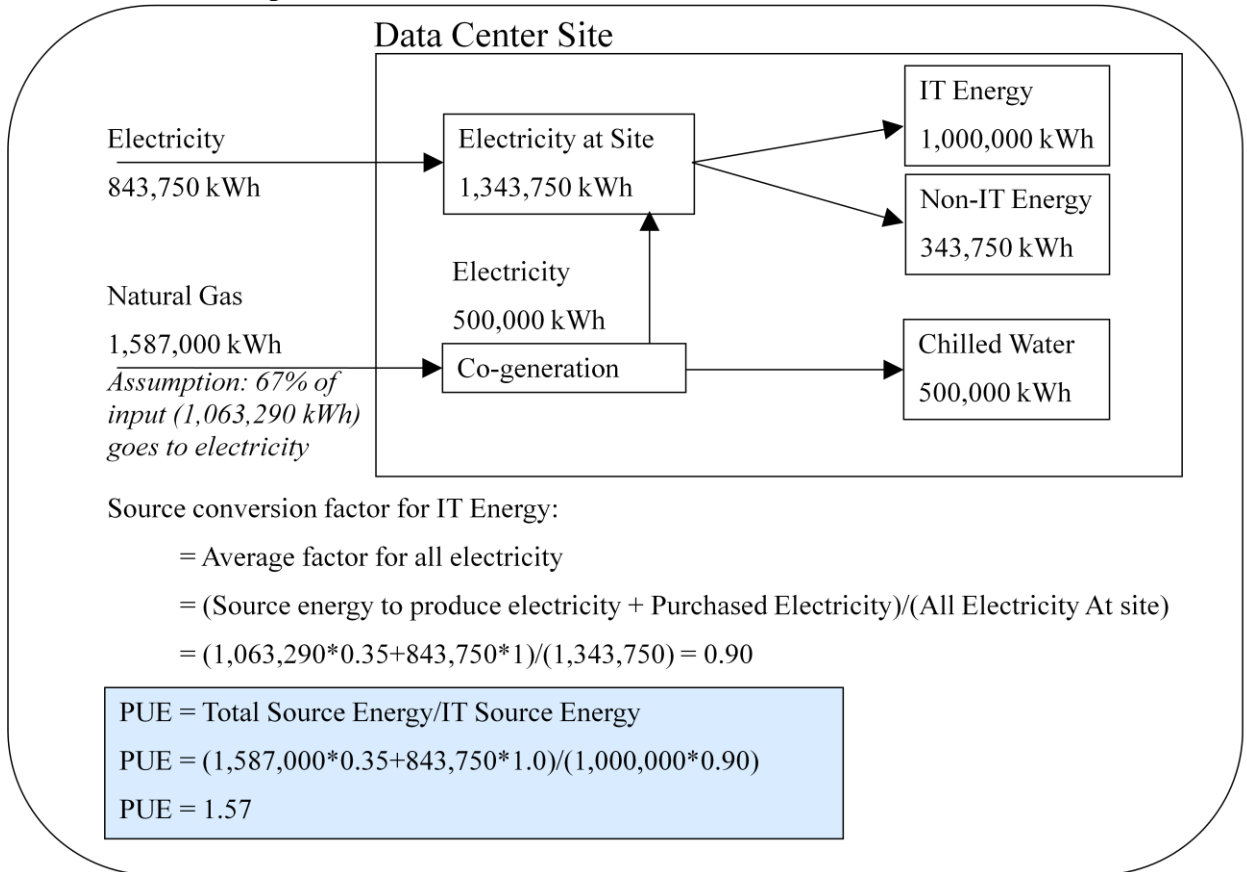
The global average source energy weighting factors shall be:

<i>Energy Type</i>	<i>Weighting Factor</i>
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



○ 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 can 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 also 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

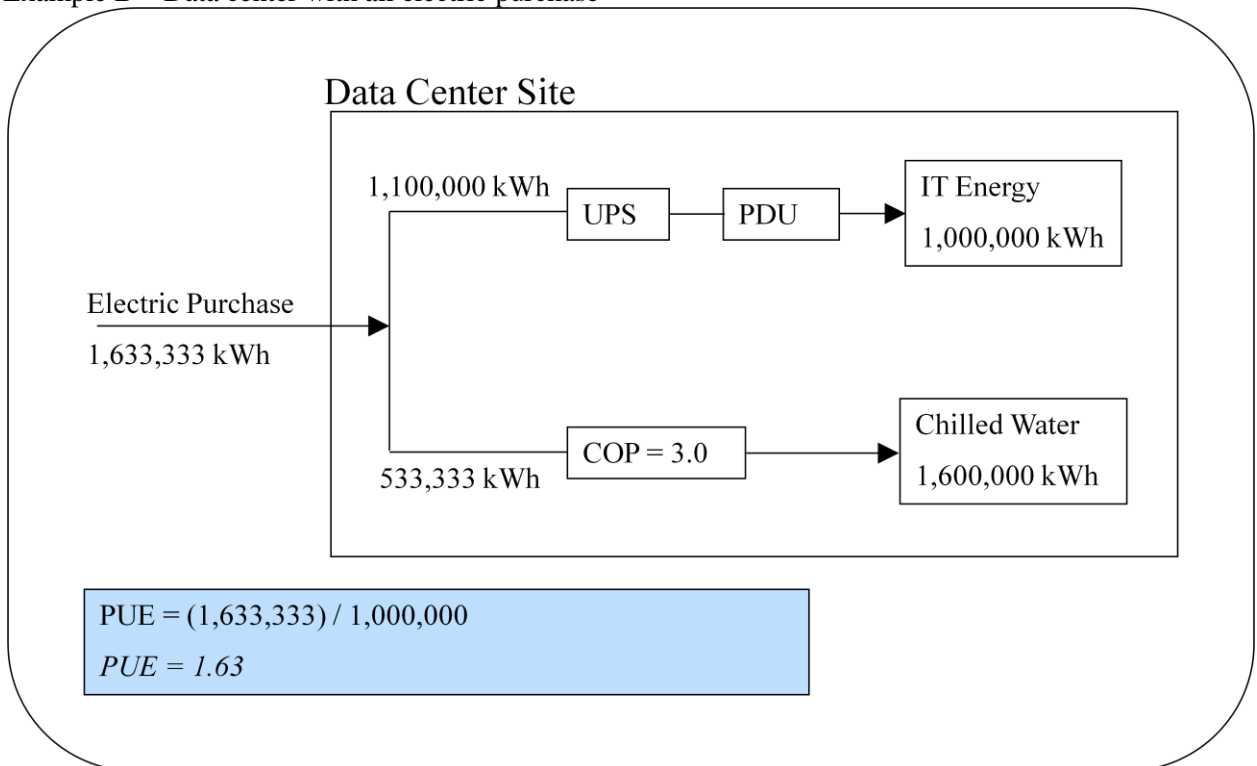
much of that energy should be allocated to the data center traffic on the 5th floor is believed to be a point of diminishing returns. The proportional load for the elevator is insignificant in the PUE calculation.

- 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.

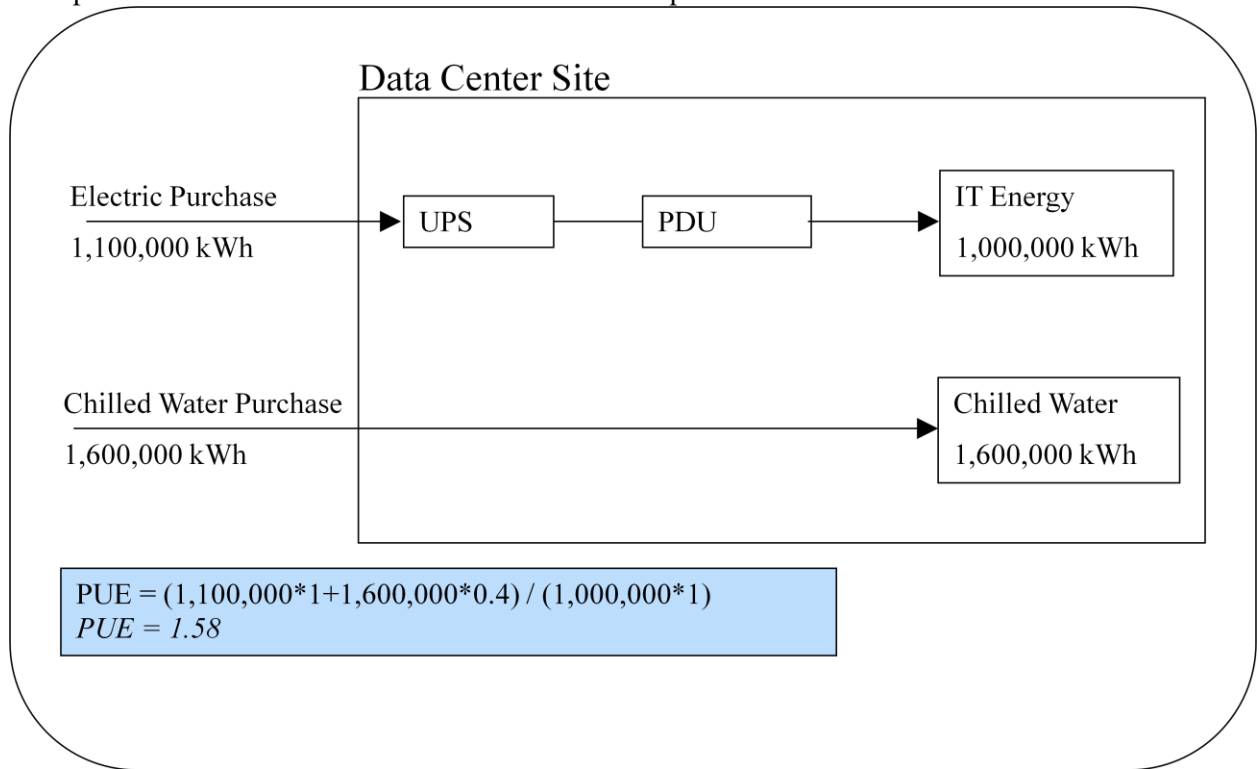
Appendix B – PUE Illustrative Calculation Examples

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:

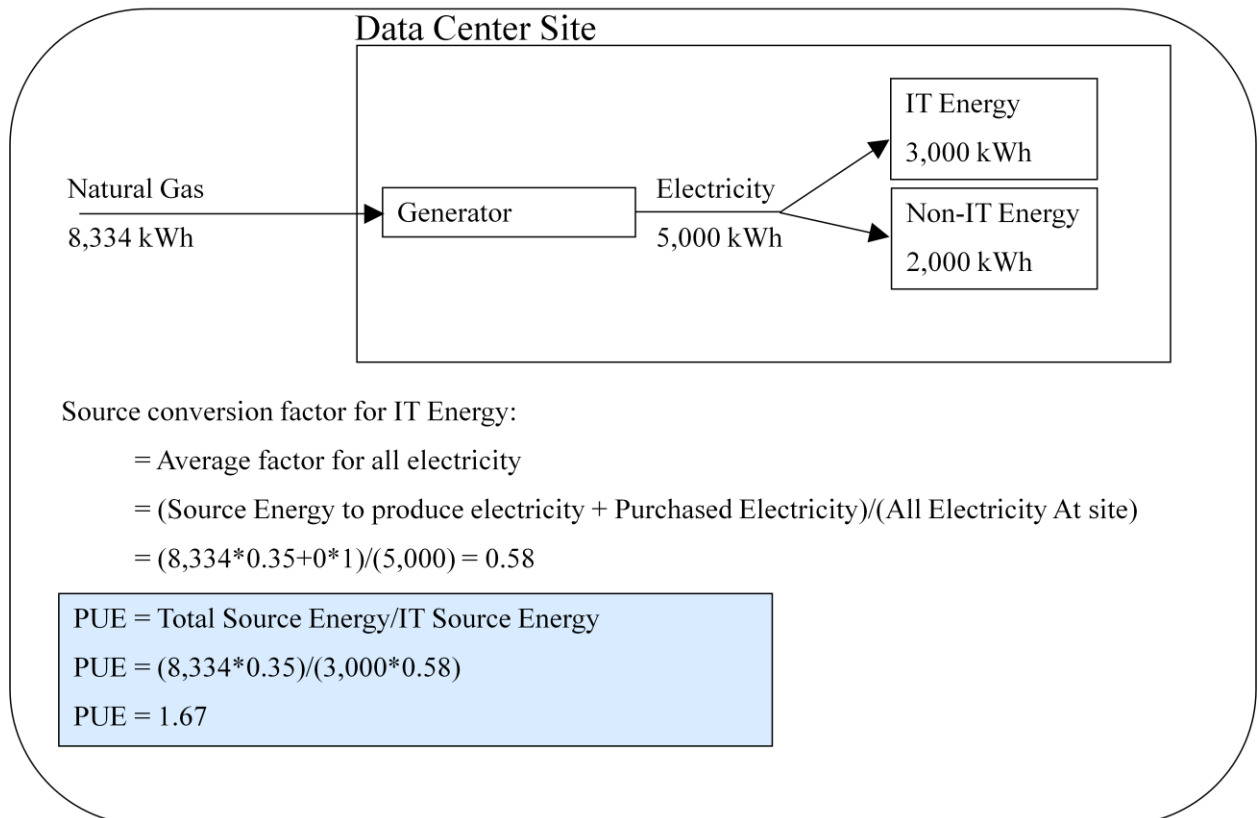
- Example B – Data center with all electric purchase



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



- Example D – Data center with natural gas purchase



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

