OPEN DATA CENTER ALLIANCE℠ PROOF OF CONCEPT: CARBON FOOTPRINT AND ENERGY EFFICIENCY REV. 1.0

TABLE OF CONTENTS

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OPEN DATA CENTER ALLIANCE[SM] PROOF OF CONCEPT: CARBON FOOTPRINT AND ENERGY EFFICIENCY REV. 1.0

EXECUTIVE SUMMARY

The release of Open Data Center Alliance[sm] Usage Model: Carbon Footprint and Energy Efficiency Rev. 2.0[1] established the fundamental requirements to create an open, standardized framework for calculating the carbon footprint generated by cloud services. The Open Data Center Alliance (ODCA) strongly advocates the use of green power sources, which can significantly help lower CO_2 emissions, while recognizing that such sources are not available at every location. In all instances, the most efficient use of power, regardless of the method of generation, can have a large impact on the overall carbon footprint of cloud service workloads.

The Carbon Footprint and Energy Efficiency proof of concept (this document) implements and extends the requirements introduced in the ODCA Carbon Footprint and Energy Efficiency usage model to a real-world computing environment, using test scenarios to demonstrate the techniques for measuring and assessing the carbon footprint of IT operations from the perspective of a data center operator, a cloud service provider, and a cloud subscriber.

The proof of concept (PoC) was facilitated by the ODCA Regulation and Ecosystem workgroup[2] with participation from ODCA member organizations including BMW, Datapipe, and Verne Global; and supported by Atos, Intel, National Australia Bank (NAB), and T-Systems. The PoC participants—BMW, Datapipe, and Verne Global—expressed a desire to conduct PoC testing to further enhance energy efficiency in their own business operations and to help refine the methodology through which enterprises can track and measure carbon footprints. The PoC objectives included testing and validating the requirements, methods, and recommendations from the ODCA usage model document, and deriving real-world insights from carbon-emission data for enterprises using cloud computing.

The test results, detailed in the sections PoC Test 1: Predicting and Tracking CO_2 Emissions and PoC Test 2: Allocating Carbon Usage to Specific Cloud Subscribers, demonstrate an effective technique for computing the aggregate carbon footprint of a data center, represented by Verne Global data center in Iceland. The PoC subsequently apportioned individual carbon emission values to cloud subscribers and cloud providers offering services to multiple customers through the data center. The ODCA recommends best practices for achieving high levels of energy efficiency in cloud-computing environments both within the usage model document and this document.

By enabling contributors to exchange and share the knowledge gained in validating and testing usage models, our entire member community benefits, as do other organizations that rely on the data and information that ODCA produces for the cloud-services industry.

This document relies, in part, on the work of The Green Grid, which provides many of the facts and methods to back up our good intentions.

The adoption of cloud services in and of itself can make a positive contribution to helping reduce the energy expenditures of data centers worldwide. Analysis conducted by Pike Research[3] demonstrated that widespread adoption of cloud computing in data centers—using software-as-a-service (SaaS), infrastructure-as-a-service (IaaS), and platform-as-a-service (PaaS) models—could effectively cut energy expenditures by 38 percent. To further emphasize the business advantages of lowering carbon emissions, figures being released from the Fifth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC) suggest that aggressively lowering carbon emissions can be compatible with strong economic growth worldwide. Using new tools for projecting future climates and economies—referred to as "Representative Concentration Pathways"—the modeling incorporates numerous factors to illustrate economic probabilities if governments take an active policy stance to cut carbon emissions.[4]

[1] See www.opendatacenteralliance.org/library

[2] See www.opendatacenteralliance.org/ourwork/regulationworkgroup. The ODCA Regulation and Ecosystem workgroup exists to influence and accelerate enterprise cloud adoption and regulatory compliance through the implementation of sustained, cost-effective, and integrated regulatory compliance controls and practices to balance regulatory obligations with innovation and strategic business value.

[3] www.navigantresearch.com/newsroom/cloud-computing-to-reduce-global-data-center-energy-expenditures-by-38-in-2020

[4] http://tntcat.iiasa.ac.at:8787/RcpDb/dsd?Action=htmlpage&page=welcome

By simply choosing to use cloud-computing services, as the Pike Research study indicates, an organization can substantially reduce its carbon footprint. There are additional opportunities to enhance energy efficiency in the data center—with the corresponding benefit of a further reduction in carbon emissions at several stages, from improving the power plant efficiency to following energy-efficient software guidelines[5] to create the business applications running on the servers (see Figure 1).

Energy Inefficiency in a Conventional Data Center

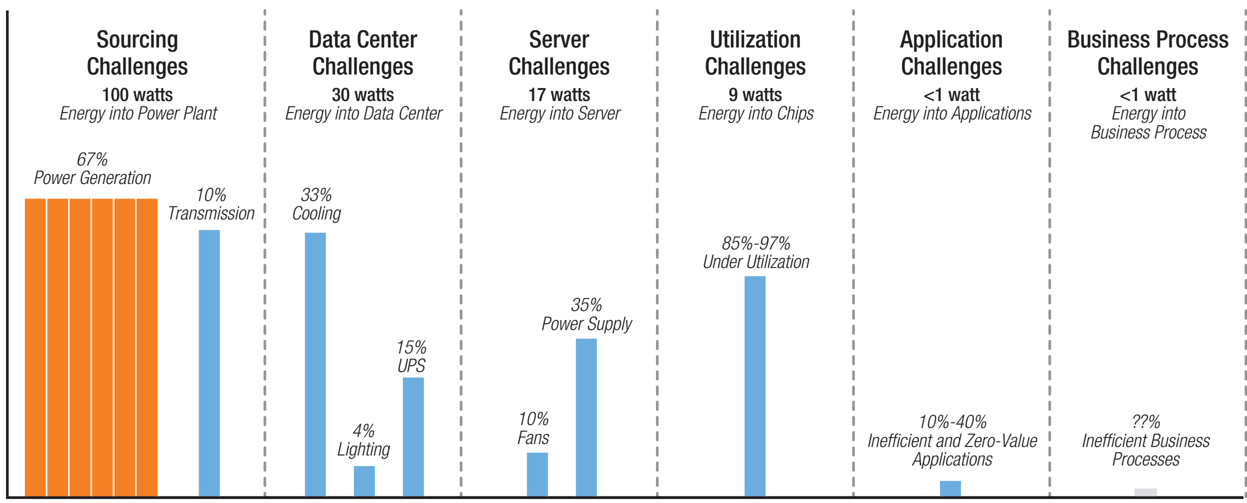

Figure 1. Relative energy losses that occur in the data center, beginning with energy generation from the power plant.
Courtesy Hewlett-Packard and Rocky Mountain Institute

BACKGROUND – CARBON FOOTPRINT AND ENERGY EFFICIENCY USAGE MODEL

The Open Data Center Alliance (ODCA) is working actively to shape the future of cloud computing—a future based on open, interoperable standards and development of a unified vision for cloud requirements. The ODCA's membership includes enterprises that represent more than $100B in annual IT expenditures. The ODCA Technical Workgroups[6] are defining a new class of IT requirements for the transformation of data center computing.

To move beyond a simple, academic approach to content, ODCA actively pursues opportunities to work within the member community and execute proof-of-concept (PoC) testing to validate the usage models. This PoC, coordinated by the ODCA Regulation and Ecosystem Workgroup,[7] investigates and validates the ODCA Usage Model: Carbon Footprint and Energy Efficiency Rev. 2.0.[8]

The Carbon Footprint and Energy Efficiency usage model describes a framework for determining the overall carbon footprint associated with cloud services. The combination of this framework and the ODCA Usage: Standard Units of Measure for IaaS Rev. 1.1[9] provides enterprises a standard, verifiable method to measure and assess the amount of CO_2 created as a by-product of their data center operations.

The amount of carbon produced can be derived from the following formula (which is an integral part of the test measurements and calculations applied in this PoC):

$$\left[\begin{array}{l}\textit{amount of IT equipment}\\ \textit{used, in Standard Units}\end{array}\right] \times \left[\begin{array}{l}\textit{kWh electricity}\\ \textit{used per Unit}\end{array}\right] \times \left[\begin{array}{l}\textit{energy overhead}\\ \textit{of data center}\end{array}\right] \times \left[\begin{array}{l}\textit{carbon emissions of}\\ \textit{of electricity source(s)}\\ +\ \textit{transmission losses}\end{array}\right]$$

More information about this topic appears in the ODCA Usage Model: Carbon Footprint and Energy Efficiency Rev. 2.0 and in the section Relationship between Emissions and Efficiency.

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5 http://software.intel.com/en-us/articles/energy-efficient-software-guidelines
6 See www.opendatacenteralliance.org/ourwork/technicalworkgroups
7 See www.opendatacenteralliance.org/ourwork/regulationworkgroup
8 See www.opendatacenteralliance.org/library
9 See www.opendatacenteralliance.org/library

Carbon Footprint and Energy Efficiency – Why It Matters

The ODCA Regulation and Ecosystem workgroup[10] recognizes that reducing CO_2 emissions and lowering the carbon footprint of businesses represent a unique value proposition to strengthen the cloud business case. As reduction of CO_2 emissions corresponds closely to minimizing power usage, it is also a key factor in lowering the costs of IT operations.

Previously, CO_2 emission data has been available at only the data center level. For cloud computing services, data centers have become less and less unique per company and are now linked to dynamic infrastructure where services are sometimes delivered from multiple data centers and cloud providers. Also, some IT services are delivered as a "black box" from the cloud or even outsourced, making it difficult to assess the carbon footprint. The industry is also moving away from the notion that an organization can jettison its carbon impact by simply having someone else take it over.

In the interests of sustainable and responsible business practices, the ODCA recognizes the growing requirement to measure and track the carbon footprint of services and products in an equitable and transparent manner. A standardized and consistent approach can assist cloud subscribers in evaluating vendors based on a common framework and select service providers that help reduce the organization's carbon footprint.

Proof-of-Concept Objectives

This PoC was conducted to test the Carbon Footprint and Energy Efficiency usage model within a real-world cloud-computing environment and gain insights from the cloud ecosystem and PoC participants. The ODCA aimed to test and demonstrate the following:

- Measure existing cloud services for carbon emissions and review the test results and insights against the ODCA Usage Model: Carbon Footprint and Energy Efficiency Rev. 2.0,[11] demonstrating real-world implementation of ODCA requirements.
- Assess the business value proposition of the usage model and benefits associated with energy efficiency and carbon footprint reduction by benchmarking cloud services and operations for efficiency, cost, and key performance indicators. To ensure coverage, the PoC was conducted through an **end-to-end** cloud services ecosystem including a cloud data center operator, cloud service provider, and cloud subscriber.
- Identify current gaps related to inadequate or missing standards that make it difficult to provide carbon footprint measurements, and recommend future industry actions.
- Demonstrate the value of transparency of data center operations that support carbon footprint measurement, and encourage energy efficiency. Additionally review the effective management of data center operations, highlighting efficiencies that can be gained with next-generation technology and cloud services based on green-computing practices, combined with infrastructure lifecycle management.
- Review the significance of green computing in the context of cloud service providers and data center operators responding to requests for proposals, and accommodate customer requirements to deliver green and energy-efficient computing.

Ultimately these objectives would help strengthen industry advocacy of ODCA usage model and requirements, and encourage building data centers and services based on green-computing objectives and energy-efficiency practices.

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[10] See www.opendatacenteralliance.org/ourwork/regulationworkgroup

[11] See www.opendatacenteralliance.org/library

THE PROOF-OF-CONCEPT TEAM

Verne Global

Verne Global owns and operates a 45-acre data center campus in Keflavik, Iceland. As a strategic location between the world's two largest data center markets, Europe and North America, Verne Global is addressing two key issues facing today's data revolution: power pricing and availability.

The company offers data center decision makers an opportunity to maximize efficiency with natural free cooling solutions year round, reduce costs with long-term fixed cost power options, and minimize impact with 100-percent renewable energy sources. Clients can meet their corporate objectives by providing a scalable solution that addresses both their immediate and future power requirements.

Verne Global is contributing to the PoC from a **data center operator** perspective. As a leading operator of data centers sourced from renewable energy, Verne Global envisioned the following value proposition from the PoC:

- Increase the awareness of the ODCA Carbon Footprint and Energy Efficiency usage model.
- Offer customers a means to include standardized carbon footprint values when evaluating services and making purchasing decisions.
- Refine techniques for improving energy efficiency delivered to customers with varying requirements and build a standardized framework around the reporting and tracking of related data.
- Make it easier for customers to report their own emissions and demonstrate to boards and governing bodies that carbon footprints are being managed in a responsible way.

BMW Group

With its three brands—BMW, MINI, and Rolls-Royce—the BMW Group is the only automobile company in the world to cover all the relevant premium segments. The company is one of the world's 10 largest automobile manufacturers. With BMW, MINI, and Rolls-Royce, the BMW Group owns three of the strongest premium brands in the automobile industry today. The vehicles in the BMW Group provide outstanding product substance in terms of aesthetics, dynamics, technology and quality, and underline the company's technological and innovative leadership. Alongside a strong market position in the motorcycle sector, the company also enjoys great success in the financial services industry.

BMW's participation in the PoC is from a **cloud subscriber** perspective. BMW envisioned the following value proposition from the PoC:

- Establish a consistent method across BMW facilities worldwide to measure the carbon footprint of data centers.
- Create a baseline of carbon efficiency to achieve the sustainability goals of the BMW Group.
- Assess future suppliers of cloud services more effectively.
- Improve purchasing decision making in respect to IT operations.

Datapipe

Datapipe is the single provider solution for optimizing, managing, and securing mission-critical IT services for the enterprise. Its areas of expertise include private and public cloud, Health Insurance Portability and Accountability Act (HIPAA) and PCI compliance, security, database, network, storage and disaster recovery. Datapipe operates data centers in influential technical and financial markets, including New York Metro; Ashburn, VA; Silicon Valley; Iceland; London; Tel Aviv; Hong Kong; Shanghai; and Singapore.

Datapipe is participating in the PoC from a **cloud service provider** perspective.

As a solution provider for managing and securing mission-critical IT services, Datapipe envisioned the following value proposition from the PoC:

- Demonstrate thought leadership for green cloud computing.
- Help formulate and shape the standards by which cloud computing will be evaluated by businesses for carbon footprint and energy efficiency.
- Introduce Datapipe green cloud services to new markets through this leadership and formulation.
- Effectively position products and solutions to customers interested in energy efficiency.

Other Participants

As described earlier, the PoC was supported by Atos, Intel, NAB, and T-Systems.

PROOF OF CONCEPT – SYSTEM UNDER TEST

Roles of PoC Participants

The participants in this PoC represented three different roles within a cloud services ecosystem:

- **Data center facility operator.** Verne Global maintains responsibility for the physical infrastructure of the data center, to the level where power is provided to the server racks.
- **Cloud service provider.** Datapipe uses the facility provided by Verne Global to house the servers and equipment that it uses to provide a full range of cloud services for customers.
- **Cloud service subscriber.** BMW Group's engagement takes advantage of the facility infrastructure to deploy and operate a compute-intensive simulator application.

Data Center Infrastructure and Components

End users rely on the performance of applications that run on the infrastructure in data centers. In order for the applications to run at performance levels mandated by stakeholders, several layers of services are required.

- At the base level, the data center operator provides physical space for servers and networking equipment, protected electrical power for servers and networking equipment, heat rejection from the computer rooms, and physical security.
- Applications can be deployed directly on the operating systems of the bare metal servers, directly on the operating systems of virtualized or cloud-enabled virtual machines (IaaS), or within application platform environments (PaaS).
- Data centers typically have shared components, including cooling equipment, external network access devices, uninterruptable power supplies, and storage and backup infrastructure (depending on the configuration, this component can also be customer specific).

Within the data center, there are also tenant-specific components that can be more dynamic under certain usage scenarios (such as virtual machines).

CO_2 usage of specific components can be allocated to the tenant using that component, whereas shared components need to be allocated based on individual usage. Allocation for shared components can also be divided among the tenants using whatever formula best fits the scenario.

As shown in Figure 2, the CO_2 usage for the PoC was allocated within the Verne Global data center across BMW Group's deployed simulator application and Datapipe customers. Datapipe individually tracked, monitored, and reported carbon footprint figures at the component level, including servers, virtual machines, and network equipment. Verne Global managed and reported shared components, including cooling equipment, power supplies, backup equipment, and storage.

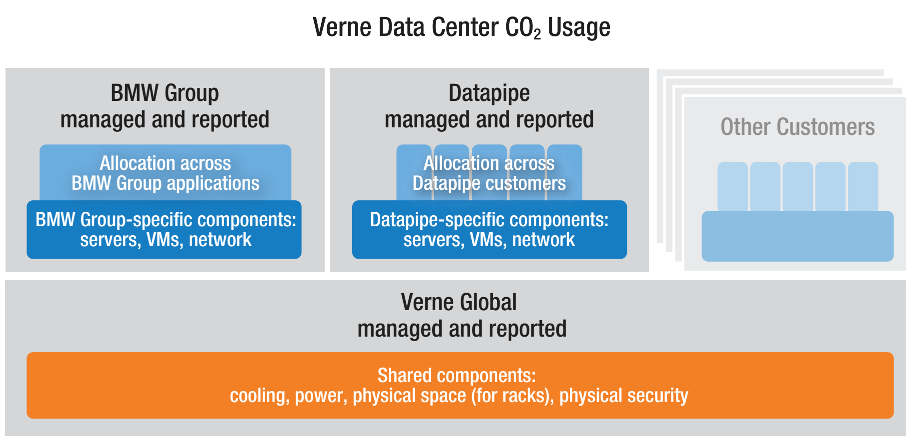

Figure 2. System under test.

The system components incorporated in the BMW Group high-performance computing (HPC) cell used as the basis for testing were as follows:

- Servers per cell:
  - 2 Gateway Node: DL360p Gen8, 1 x E5-2670
  - 2 Fileserver Node: DL380p Gen8, 2 x E5-2670
  - 118 Compute Node: HP SL230s Gen8, 2 x E5-2670
  - 10 Big Node: DL360p Gen8, 2 x E5-2670
- Network per cell:
  - 6 x Mellanox/Voltaire 4036 InfiniBand-Switch 36 Ports
  - 1 x HP 2910 48 Port, 3 x HP 2910 48 Port
  - 1 x HP 2610 48 Port, 5 x HP 2610 24 Port

Note: This configuration is specified for one of the several customers based on the Verne Global campus.

Regulatory Context

For the tests conducted within this PoC, the power consumption remained below the 20-megawatt level at which certain government regulations come into play, including the European Union Emissions Trading System (EU ETS).

As many government bodies around the world are taking a more aggressive stance toward regulating carbon emissions, enterprises should be aware of new and existing regulations that could impact their use of cloud services. The following text provides a brief summary of some regulations related to carbon emissions.

For high-emitting industry sectors, the cap-and-trade system created by the EU ETS establishes a limit on overall emissions with a specified yearly reduction that must be met. Enterprises can buy and sell emission allowances to meet the mandates; this provides a mechanism that offers flexibility in cost effectively complying with regulations and a strong incentive to progressively reduce emissions over time. This system applies to power stations and manufacturing plants in 27 EU member states and also applies to Croatia, Iceland, Liechtenstein, and Norway. To comply with the regulations, businesses are required to track, monitor, and report emissions for EU ETS verification on an annual basis. Emission allowances are granted and credits can be purchased, functioning as a form of currency, driving investment in emission-saving projects and encouraging enterprises to transition to energy sources with smaller carbon footprints.

In the United States, a Greenhouse Gas Reporting Program (GHGRP) was initiated in 2010 by the United States Environmental Protection Agency (EPA), data from which is published online as part of the Greenhouse Gas Data Publication Tool.[12] This information can be used to investigate CO_2 by facilities, plants, localities, and other criteria, which may be helpful in determining the carbon footprints of power sources available to data center operators. As of the date of this publication, specific federal regulations dealing with carbon emissions related to data center operations in the United States have not been established, but EPA regulations that involve the greenhouse gas emissions of power plants will penalize inefficiency, and costs are likely to be passed through to data center operators. President Obama has instructed the EPA to establish a nationwide set of controls for greenhouse gases, but no projected dates for completion of this initiative have been stated.

The State of California passed legislation[13] that took effect January 1, 2013 establishing a cap-and-trade system for power plants with the expectation that data centers in the state—being among the largest energy consumers—will be directly affected. Under this system, entities that exceed the cap can purchase allowances in the cap-and-trade market, reduce fossil fuel use, or take other measures to increase energy efficiency.

As of this publication release, The Green Grid Association is finalizing a paper that evaluates the impact on data center electricity rates of utilities transitioning to less carbon-intensive energy sources.

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[12] www.ccdsupport.com/confluence/display/ghgp/Home

[13] www.networkworld.com/news/2013/082613-data-center-rules-273102.html?page=2

TAXONOMY

Table 1 defines the terms used throughout this document.

Table 1. Terms and definitions.

Term	Definition
Auditor	External agencies and individuals who perform audits over a specific area or market.
Carbon Disclosure Project	The Carbon Disclosure Project is an international, not-for-profit organization providing a global system for companies and cities to measure, disclose, manage, and share vital environmental information.
Carbon Emission Factor (CEF)	In reference to power plant operation, the CEF is the amount of CO_2 emitted in kilograms per unit of kilowatt energy. This value is generally available as data from local governments in relation to individual power plants and other facilities.
Carbon Footprint	A measure of the total amount of carbon dioxide (CO_2) and methane (CH_4) emissions of a defined population, system, or activity, considering all relevant sources, sinks, and storage within the spatial and temporal boundary of the population, system, or activity of interest. This is calculated as a carbon dioxide equivalent (CO2e), using the relevant 100-year global warming potential (GWP100).
Carbon Usage Effectiveness (CUE)	The Green Grid combines two values, the PUE and the CEF, to produce the CUE for a given facility. The CUE indicates how much total energy is used. The amount of carbon emissions produced depends on whether renewal sources were used and whether carbon was offset.
Cloud Infrastructure Environment	A cloud provider's specific implementation of hardware, software, management infrastructure, and business processes and practices to implement a provider's service catalog.
Cloud Provider	An organization providing cloud services and charging cloud subscribers. A cloud provider provides services over the Internet. A cloud subscriber could be its own cloud provider, such as for private clouds.
Cloud Subscriber	A person or organization that has been authenticated to a cloud and maintains a business relationship with a cloud.
Customer Total Carbon	In this proof of concept, the sum of the utility carbon and the diesel engine-generator carbon.
Decommissioned EEE	Electronics and electrical equipment (EEE) that is put out of service and leaves the control of the organization.
Digital Service Efficiency (DSE)	A metric developed by eBay to provide a standardized means for calculating the cost, performance, and environmental impact of individual online transactions.
Electronics Disposal Efficiency (EDE)	EDE is a metric devised by The Green Grid for better understanding the recycling and disposal of IT assets. The formula divides the "weight of equipment responsibly disposed" by "the total weight of disposed." Optimally, enterprises try to get as close to 100 percent as possible.
Electronics and Electrical Equipment (EEE)	All forms of electronic devices and equipment used in business and consumer applications, most of which contain hazardous substances and require special collection, disposal, and/or recycling.
End of Current Use (EOCU)	The equipment is no longer being used for its last-identified purpose. If a piece of IT EEE is going to be repurposed or reused within an organization, that piece of IT EEE should not be considered in metric calculations.
End of Life (EOL)	When used to describe computing equipment, EOL means an individual piece that is no longer suitable for use and is intended for dismantling and recovery of spare parts, or is destined for recycling or final disposal. It also includes off-specification or new computing equipment that has been sent for recycling or final disposal.
European Union Emissions Trading System (EU ETS)	An emission trading system based on "cap and trade" principles that were established by the European Union in 2005 to address climate change. Under this system, participating installation must report emissions and avoid exceeding a cap established for that installation. Allowances for emissions are auctioned off or allocated, giving installations the opportunity to purchase allowances if they exceed their emission cap.
Greenhouse Gas Reporting Program (GHGRP)	A program initiated by the U.S. Environmental Protection Agency for the online publication of CO_2 data by facilities, plants, localities, and other criteria. The data is useful in comparing carbon footprints of power sources.
Infrastructure as a Service (IaaS)	A model of service delivery whereby the basic computing infrastructure of servers, software, and network equipment is provided as virtualized objects, controllable via a service interface. Organizations can use this infrastructure to build a platform for developing and executing applications, while avoiding the cost of purchasing, housing, and managing their own components.
Kilowatt Hour (kWh)	A unit of energy equal to one kilowatt of power consumed over the span of one hour. Electrical energy is sold based on **kWh**.
Legislator/Law Enforcement	Entity that creates, enacts, and/or enforces laws.

Term	Definition
Metering	The monitoring, controlling, and reporting of resource usage, at some level of abstraction appropriate to the type of service (for example, storage, processing, bandwidth, or active user accounts). Metering enables both the provider and consumer of the service to control and optimize usage.
Power Usage Effectiveness (PUE)	Developed by The Green Grid, PUE is a metric for determining how effective a data center is at delivering energy to IT equipment within a facility. This is calculated by the ratio of the total energy required to power the facility to the total energy consumed by the IT equipment in use. A PUE value of 1.6 or better is achieved within a well-designed data center. Typical data center values range from 1.3 to 3.0.
Representative Concentration Pathways (RCPs)	RCPs are the third generation of scenarios developed by the Intergovernmental Panel on Climate Change (IPCC) to provide a standardized means for modeling climate change.
Total Utility CEF	The utility CEF increased by the transmission losses to represent a carbon efficiency factor for the entire system (including generation and transmission).
Transmission Losses	The amount of energy lost through the distribution system from the plant to the data center.
Used Electronics and Electrical Equipment (UEEE)	Equipment that has been in use within a data center or other facility and has been replaced or is designated for recycling or disposal.
Utility Carbon	The mathematical product of total IT energy and non-IT energy (attributed to the customer's computer racks) multiplied by the total utility CEF for the facility.
Waste electronics and electrical equipment (WEEE)	Equipment designated for collection, recycling, or recovery. The WEEE Directive, initiated by the European Union, identifies six hazardous substances associated with WEEE that require special handling, including lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls, and polybrominated diphenyl ether.

PoC Test Context Diagram and Scoping

Figure 3 shows the factors that were considered in this PoC and the components that were included within the test environment. These are based on the component breakdowns originally established in the ODCA Usage Model: Carbon Footprint and Energy Efficiency Rev. 2.0.[14]

The scope of testing is limited to the data center itself. Obtaining precise figures on embedded carbon as a factor in equipment manufacture and disposal is discussed, but acquiring these values from original equipment manufacturers in time for the release of this document was not possible. To responsibly and accurately report carbon emission values, enterprises will need to insist on current data as part of the criteria of vendor selection. As the industry as a whole moves in the direction of accurate carbon monitoring, many vendors are becoming more forthcoming and open in their reporting of electronics disposal efficiency (EDE)[15] data.

EDE, a metric developed by The Green Grid, offers a benchmark based on the percentage of decommissioned information technology electronics and electrical equipment that is disposed of in a responsible manner. The carbon emission factor (CEF),[16] represented as the level of CO_2 emitted in kilograms (KG) per unit of kilowatt (kW) energy, is typically derived from data published by the utility companies where the power is sourced.

Note that in the case of Verne Global, because the level of carbon emissions from the power source is so low, the CEF is represented in **grams per kWh**.

The power usage effectiveness (PUE)[17] value that applies to the data center operations represents the energy overhead of the facility. The PUE consists of the ratio of the total energy required to power a facility to the total energy consumed by the IT equipment. When combined with the CEF, a carbon usage effectiveness (CUE) value can be obtained, provided a standardized basis for comparing carbon footprints among data centers.

This PoC focuses on only those factors associated with the operations occurring within the data center. The full environmental burden over the lifecycle of the data center and the equipment in use depends on decisions made by the IT customers. Likewise, the CUE and PUE values are based solely on data center operations.

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14 See www.opendatacenteralliance.org/library

15 The applicable metric was developed by The Green Grid Association, "Electronics Disposal Efficiency (EDE): An IT Recycling Metric for Enterprises and Data Centers," White Paper #53. www.thegreengrid.org. EDE is a trademark of The Green Grid Association.

16 The applicable metric was developed by The Green Grid Association. See the "Carbon Usage Effectiveness (CUE): a Green Grid Data Center Sustainability Metric," White Paper #32. www.thegreengrid.org. CUE is a trademark of The Green Grid Association.

17 The applicable metric was developed by The Green Grid Association. See the "Green Grid Data Center Power Efficiency Metrics: PUE and DCiE," White Paper #06. www.thegreengrid.org. PUE and DCiE are trademarks of The Green Grid Association.

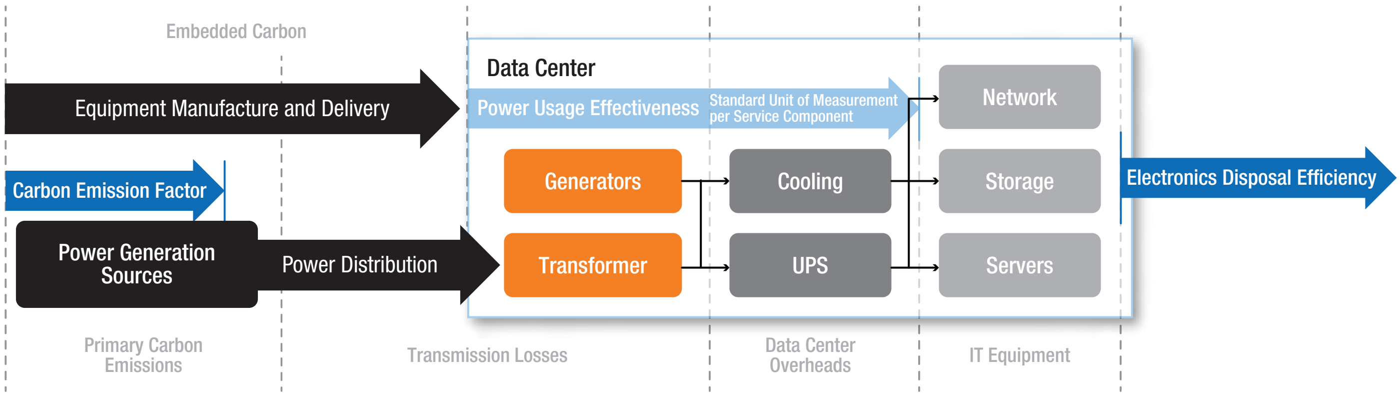

Figure 3. Major components tested as part of the proof of concept.

POC TEST 1: PREDICTING AND TRACKING CO_2 EMISSIONS

The first test was conducted to predict CO_2 emissions and track actual emissions through technical capabilities instituted by providers of cloud services. The objective was to refine techniques for standardized reporting to assist cloud subscribers, allowing them to predict CO_2 emissions and to track and record actual emissions produced on their behalf. The cloud provider must have the technical capability to predict and track these emissions in an auditable manner.

Figure 4 illustrates the monitoring points Verne Global set up to determine customer IT loads and calculate PUE values. To provide information to customers, Verne Global develops an emission rate per kWh. Once this emissions rate has been established, Verne Global can apportion it to customers based on their energy usage.

The calculated CEF values for Verne Global as compared to reference sources for bituminous coal and natural gas are:

- Verne campus (including transmission losses) - 0.680 grams/kWh
- Bituminous coal (not including transmission losses) - 944 grams/kWh
- Natural gas (not including transmission losses) - 553 grams/kWh

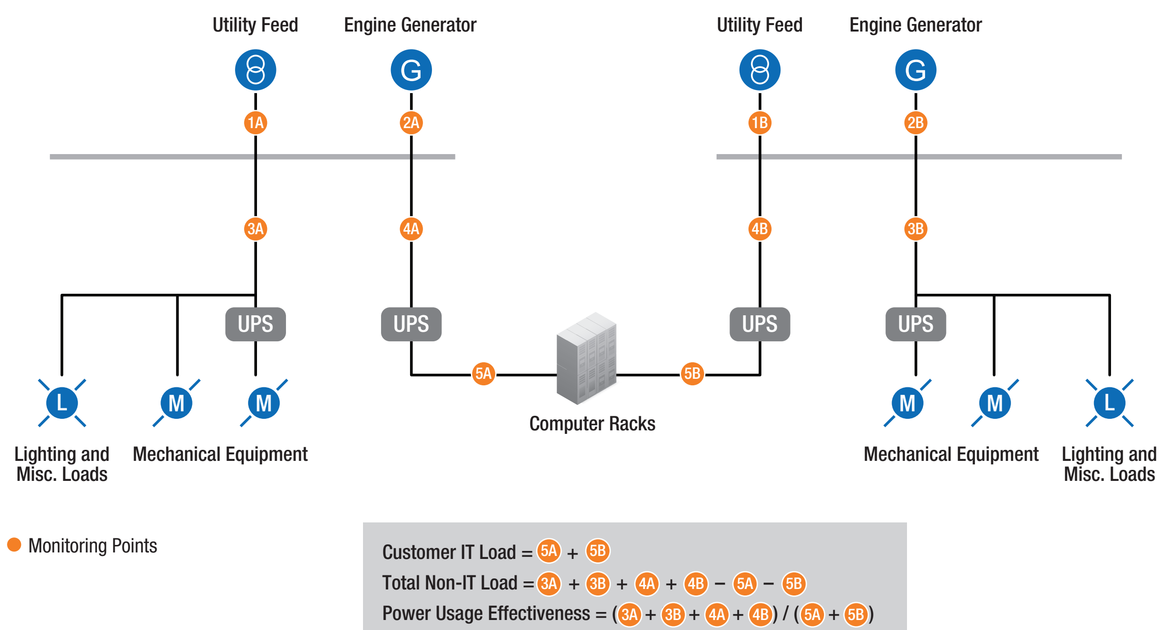

Figure 4. Monitoring points set up by Verne Global for the testing.

Datapipe Apportionment of Carbon Emissions

For calculating and apportioning energy use and carbon use among its customers, Datapipe foresees an approach that defines three levels of server capabilities, generically referred to as small, medium, and large, and makes calculation based on the energy delivered by Verne Global to individual server racks, the degree to which the rack is populated, and the level of server capabilities for each customer within that rack.

By calculating measurements for each server as a percentage of the power being delivered to the rack, Datapipe is able to determine a close approximation of the carbon footprint per cloud instance (depending on whether it is a small, medium, or large instance).

The Datapipe Sample Customer in the following Datapipe carbon footprint report is considered a **large** instance.

Datapipe Technical Description

The definitions of the measurements included in the Datapipe reports are as follows:

- **Start of period.** Indicates the date of the start of the monitoring period. Assumes midnight 00.00 UTC for the time of the period start.
- **End of period.** Indicates the end date of the monitoring period. Assumes midnight 00.00 UTC for the time of the period end.
- **Average cloud instance power usage.** Represents the measured total power used by a typical cloud instance as provisioned for the Datapipe Sample Customer. This includes the power for the virtual machine, the network gear, and the associated storage.
- **Total cloud instances.** Denotes the total number of cloud instances provisioned for the Datapipe Sample Customer.
- **PUE.** Expresses the ratio of the total energy to the IT energy for the entire monitoring period. The PUE number is based on Verne Global's calculation for the entire Datapipe deployment. Datapipe is allocating its PUE evenly across all customers based on their IT energy usage, which would be the average PUE over the monitoring period.
- **IT energy.** Indicates the measured energy in kilowatt-hours for the power going into the computer racks. In the Verne Global facility, the energy is measured at the circuit breaker on the Starline busway that provides the redundant feeds to the computer racks.
- **Non-IT energy.** Represents the energy other than the IT energy attributed to the customer's computer racks. The non-IT energy includes UPS losses, HVAC power, lighting, and other miscellaneous loads.
- **Total energy.** Consists of the sum of the IT energy and the non-IT energy and represents the total energy attributed to the customer's computer racks.
- **Utility CEF.** Represents the amount of carbon in grams that is released for each kilowatt hour of energy generated by the upstream utility power provider. This figure is based on the 2012 Landsvirkjun environmental report for carbon attributed to hydroelectric generation.[18]
- **Transmission losses.** The utility CEF must be increased by 4.55 percent, which is the 2012 reported transmission losses for the Landsnet (Icelandic National Transmission Company) system.
- **Total utility CEF.** Represents the utility CEF increased by the transmission losses to represent a CEF for the entire system, including generation and transmission.
- **Utility CUE.** Represents the mathematical product of the total utility CEF and the PUE.
- **Diesel engine-generator carbon.** Expresses the total carbon attributed to the customer for the monitoring period. Note that the total engine-generator carbon is calculated by measuring total diesel fuel burned. The total engine-generator carbon for the Verne Global site is divided up among the customers based on total energy.
- **Utility carbon.** Consists of the mathematical product of total energy and total utility CEF.
- **Customer total carbon.** Consists of the sum of utility carbon and diesel engine-generator carbon.
- **Customer total CUE.** Expresses the CUE for both utility and diesel engine-generator sources. The customer total CUE is the ratio of customer total carbon to IT Energy.

[18] For the coal and natural gas sources, the information was derived from the U.S. Energy Information Administration as a basis for the CEF figures. The reference source is www.eia.gov/tools/faqs/faq.cfm?id=74&t=11.

Datapipe Carbon Reports - Actual and Hypothetical

Tables 2 through 4 show actual and hypothetical recorded values for Datapipe's carbon footprint report.

Table 2. Actual Datapipe report for the Datapipe Sample Customer

Actual recorded values through geothermal and hydropower

Measure	Value
Start of Period	13 SEP 13
End of Period	19 SEP 13
Average Cloud Instance Power Usage	202 W
Total Cloud Instances	28
Period Hours	144 hours
Power Usage Effectiveness (PUE)	1.39
IT Energy	814.5 kWh
Non-IT Energy	317.6 kWh
Total Energy	1,132.1 kWh
Utility Carbon Emission Factor (CEF)	0.65 g/kWh
Average Transmission Losses	4.55%
Total Utility CEF	0.68 g/kWh
Utility Carbon Usage Effectiveness (CUE)	0.94 g/kWh
Diesel Engine-Generator Carbon	1.18 kg
Utility Carbon	1.07 kg
Customer Total Carbon	2.25 kg
Customer Total CUE	1.8 g/kWh

Table 3. Hypothetical carbon report as compared with Table 2

Assuming a natural gas utility source – for comparison purposes only

Measure	Value
Start of Period	13 SEP 13
End of Period	19 SEP 13
Average Cloud Instance Power Usage	202 W
Total Cloud Instances	28
Period Hours	144 hours
Power Usage Effectiveness (PUE)	1.39
IT Energy	814.5 kWh
Non-IT Energy	317.6 kWh
Total Energy	1,132.1 kWh
Utility Carbon Emission Factor (CEF)	553 g/kWh
Average Transmission Losses	4.55%
Total Utility CEF	578 g/kWh
Utility Carbon Usage Effectiveness (CUE)	804 g/kWh
Diesel Engine-Generator Carbon	1.18 kg
Utility Carbon	910 kg
Customer Total Carbon	911 kg
Customer Total CUE	1,119 g/kWh

Table 4. Hypothetical carbon report as compared with Table 2

Assuming a coal utility source – for comparison purposes only

Measure	Value
Start of Period	13 SEP 13
End of Period	19 SEP 13
Average Cloud Instance Power Usage	202 W
Total Cloud Instances	28
Period Hours	144 hours
Power Usage Effectiveness (PUE)	1.39
IT Energy	814.5 kWh
Non-IT Energy	317.6 kWh
Total Energy	1,132.1 kWh
Utility Carbon Emission Factor (CEF)	944 g/kWh
Average Transmission Losses	4.55%
Total Utility CEF	987 g/kWh
Utility Carbon Usage Effectiveness (CUE)	1,372 g/kWh
Diesel Engine-Generator Carbon	1.18 kg
Utility Carbon	1,553 kg
Customer Total Carbon	1,554 kg
Customer Total CUE	1,908 g/kWh

PoC Test 2: Allocating Carbon Usage to Specific Cloud Subscribers

Test Objective: Apportioning energy usage and emissions among cloud subscribers

The second test was conducted to determine energy usage and carbon emissions among various cloud subscribers, where each uses only a portion of a cloud provider's data center, and they themselves possibly use multiple providers. Cloud providers must have methods for allocating carbon usage to specific cloud subscribers.

As in the prior test, in order to provide information to its customers Verne Global develops an emission rate per kWh. Once this emissions rate has been established, Verne Global can "charge" this to customers based on their energy usage.

Verne Global calculates total energy usage per customer and compares accordingly. However, because the available information, accessible to Verne Global, does not include the computational work that is performed per unit of energy, calculations cannot be made in terms of the quality of the computational work being performed per unit of energy or carbon.

Data calculations are completed by metering the customer UPS output energy and calculating the PUE for each customer.

BMW Group Technical Description

The definitions of the measurements included in the BMW Group reports are as follows:

- **Start of period.** Indicates the date of the start of the monitoring period. Assumes midnight 00.00 UTC for the time of the period start.
- **End of period.** Indicates the end date of the monitoring period. Assumes midnight 00.00 UTC for the time of the period end.
- **IT energy.** Indicates the measured energy in kilowatt-hours for the power going into the computer racks. In the Verne Global facility, the energy is measured at the circuit breaker on the Starline busway that provides the redundant feeds to the computer racks.
- **Non-IT energy.** Represents the energy other than the IT energy attributed to the customer's computer racks. The non-IT energy includes UPS losses, HVAC power, lighting, and other miscellaneous loads.
- **Total energy.** Consists of the sum of the IT energy and the non-IT energy and represents the total energy attributed to the customer's computer racks.
- **PUE.** Expresses the ratio of the total energy to the IT energy for the entire monitoring period. This would be the average PUE over the monitoring period.
- **Utility CEF.** Represents the amount of carbon in grams that is released for each kilowatt hour of energy generated by the upstream utility power provider. This figure is based on the 2012 Landsvirkjun environmental report for carbon attributed to hydroelectric generation.[19]
- **Transmission losses.** The utility CEF must be increased by 4.55 percent, which is the 2012 reported transmission losses for the Landsnet (Icelandic National Transmission Company) system.
- **Total utility CEF.** Represents the utility CEF increased by the transmission losses to represent a CEF for the entire system, including generation and transmission.
- **Utility carbon usage effectiveness.** Represents the mathematical product of the total utility CEF and the PUE.
- **Diesel engine-generator carbon.** Expresses the total carbon attributed to the customer for the monitoring period. Note that total engine-generator carbon is calculated by measuring total diesel fuel burned. The total engine-generator carbon for the Verne Global site is divided up among customers based on total energy.
- **Utility carbon.** Consists of the mathematical product of total energy and total utility CEF.
- **Customer total carbon.** Consists of the sum of utility carbon and diesel engine-generator carbon.
- **Customer total CUE.** Expresses the CUE for both utility and diesel engine-generator sources. The customer total CUE is the ratio of customer total carbon to IT Energy.

[19] For the coal and natural gas sources, the information was derived from the U.S. Energy Information Administration as a basis for the carbon emission factor figures. The reference source is www.eia.gov/tools/faqs/faq.cfm?id=74&t=11.

BMW Group High-Performance Computing Cell Carbon Reports - Actual and Hypothetical

The following values shown in Tables 5 through 7 were obtained for the HPC cell operated by the BMW Group within the Verne Global data center.

Table 5. BMW Group HPC cell carbon report
Actual recorded values using geothermal and hydropower

Measure	Value
Start of Period	1 SEP 13
End of Period	30 SEP 13
IT Energy	23,760 kWh
Non-IT Energy	5,107 kWh
Total Energy	28,867 kWh
Power Usage Effectiveness (PUE)	1.21
Utility Carbon Emission Factor (CEF)	0.65 g/kWh
Average Transmission Losses	4.55%
Total Utility CEF	0.68 g/kWh
Utility Carbon Usage Effectiveness (CUE)	0.79 g kWh
Diesel Engine-Generator Carbon	30.1 kg
Utility Carbon	18.8 kg
Customer Total Carbon	48.9 kg
Customer Total CUE	2.1 g/kWh

Table 6. Hypothetical carbon report as compared with Table 5
Hypothetical, based on natural gas utility source – for comparison purposes only

Measure	Value
Start of Period	1 SEP 13
End of Period	30 SEP 13
IT Energy	23,760 kWh
Non-IT Energy	5,107 kWh
Total Energy	28,867 kWh
Power Usage Effectiveness (PUE)	1.21
Utility Carbon Emission Factor (CEF)	553 g/kWh
Average Transmission Losses	4.55%
Total Utility CEF	578 g/kWh
Utility Carbon Usage Effectiveness (CUE)	672 g/kWh
Diesel Engine-Generator Carbon	30.1 kg
Utility Carbon	15,963 kg
Customer Total Carbon	15,994 kg
Customer Total CUE	673 g/kWh

Table 7. Hypothetical carbon report as compared with Table 5
Hypothetical, based on a coal utility source – for comparison purposes only

Measure	Value
Start of Period	1 SEP 13
End of Period	30 SEP 13
IT Energy	23,760 kWh
Non-IT Energy	5,107 kWh
Total Energy	28,867 kWh
Power Usage Effectiveness (PUE)	1.21
Utility Carbon Emission Factor (CEF)	944 g/kWh
Average Transmission Losses	4.55%
Total Utility CEF	987 g/kWh
Utility Carbon Usage Effectiveness (CUE)	1,147 g/kWh
Diesel Engine-Generator Carbon	30.1 kg
Utility Carbon	27,250 kg
Customer Total Carbon	27,281 kg
Customer Total CUE	1,148 g/kWh

During the test configuration and procedures, participants revisited the ODCA Usage: Standard Units of Measure for IaaS.[20] to confirm that the testing followed published usage model guidelines (an excerpt from this document follows).

> The Standard Units of Measure (SUoM) could be conceptualized and established for the numbers of servers or gigabytes of storage used.
>
> The SUoM document describes the need for a standard unit for IT equipment used. What matters for most customers is the carbon generated from running their particular application workload.
>
> The electricity used per unit should not just be a "nameplate" value, because that is a maximum figure and does not indicate a real figure for normal use. For servers, the amount of electricity used tends to be around 45 to 50 percent of the nameplate value. In a virtualized environment, it is likely to have to be apportioned.
>
> Among various cloud subscribers, each will use only a portion of a cloud provider's data center, and they themselves may use multiple providers. Therefore, cloud providers must have methods for allocating carbon usage to specific cloud subscribers. And cloud subscribers must have methods for aggregating the amount of carbon used from various cloud providers and from in-house production. Carbon usage services can be billed as they are at other utility enterprises.
>
> The consensus upon test completion was that the usage model accurately reflected guidelines that could be applied to apportioning the carbon usage of specific cloud subscribers.

[20] See www.opendatacenteralliance.org/library

FLUCTUATIONS IN MEASURED AND CALCULATED VALUES

Many values and associated costs with carbon emissions can vary from time to time for any one provider. For example, PUE values fluctuate seasonally, because of weather and ambient temperatures. Verne Global monitors the overall PUE of the data center and averages this on a monthly basis. Seasonal variations are primarily related to humidification requirements at the Verne Global site. During periods when the dew point is low, humidification is a necessary requirement for the critical data hall areas.

It is expected that cloud providers and cloud subscribers will consider the impact of seasonal variations on the computations of PUE and carbon emissions.

ESTABLISHING STANDARDIZED MEASUREMENT AND AUDITING

While the PoC participants have currently not specified the need for auditing of carbon emissions for the purposes of corporate policies and regulatory obligations, the outcomes from the PoC offer a sound foundation to support such a future need, if it arises.

As discussed in the ODCA Carbon Footprint and Energy Efficiency usage model, cloud subscribers should accumulate and aggregate the data for carbon reporting, particularly since capturing and reporting this data could become a necessary part of doing business in the near future.

MEASURING EMBEDDED CARBON AND EQUIPMENT DISPOSAL EFFICIENCY

The objective is to measure and account for embedded carbon during the complete lifecycle of the equipment in use. This includes embedded carbon associated with equipment manufacturing and end-of-life electronic disposal efficiency (EDE).

Accomplishing this requires openness and transparency from the equipment manufacturers and vendors, and tracking and calculating by the equipment purchasers or leasers. As is the case for measuring data center carbon footprints in a consistent, standardized manner, assessing the amount of embedded carbon during equipment manufacturing and disposal requires the use of standardized metrics for measurement and comparison. The proposed EDE metric developed by The Green Grid creates incentives for enterprises and data centers to recycle and responsibly dispose of IT equipment. ODCA supports this initiative.

The basic formula underlying this metric is simple:

$$\text{EDE} = \frac{\text{Wt}_{\text{“Responsibly Disposed”}}}{\text{Total Wt}_{\text{“Disposed”}}}$$

Enterprises bear the responsibility to know the weight of equipment being decommissioned for recycling or disposal as well as the ultimate destination of decommissioned equipment—whether recycled or dumped at a landfill site. Under this model, enterprises strive to come as close to an EDE of 100 percent as possible.

Details of this metric are provided in White Paper #53, published by The Green Grid: Electronics Disposal Efficiency (EDE): An IT Recycling Metric for Enterprises and Data Centers.[21]

Along similar lines, The Green Grid has developed additional metrics to help enterprises evaluate and enhance data center operations. Beyond the power usage effectiveness (PUE) discussed in this document, other metrics developed by The Green Grid include data center energy productivity (DCeP),[22] energy reuse effectiveness (ERE),[23] and data center compute efficiency (DCcE).[24]

[21] The Green Grid, “Electronics Disposal Efficiency (EDE): An IT Recycling Metric for Enterprises and Data Centers. www.thegreengrid.org/en/Global/Content/white-papers/WP53-ElectronicsDisposalEfficiencyAnItRecyclingMetricforEnterprisesandDataCenters

[22] The applicable metric was developed by The Green Grid Association. www.thegreengrid.org. DCeP is a trademark of The Green Grid Association.

[23] The applicable metric was developed by The Green Grid Association. www.thegreengrid.org. ERE is a trademark of The Green Grid Association.

[24] The applicable metric was developed by The Green Grid Association. www.thegreengrid.org. DCcE is a trademark of The Green Grid Association.

RELATIONSHIP BETWEEN EMISSIONS AND EFFICIENCY

> "The PoC test results demonstrate a direct relationship between carbon emissions and power source. The PoC highlighted reduction of carbon emissions, as well as efficient use of energy as a two-pronged approach to support business needs and objectives."
>
> *—Pankaj Fichadia, Chair, ODCA Regulation and Ecosystem Workgroup*

The ODCA Carbon Footprint and Energy Efficiency usage model noted that two related concepts, energy efficiency and the carbon footprint, might be reflected respectively in the costs and climate impact of cloud services. The two indicators are not synonymous as carbon footprint is most heavily related to the source of power for the site, not to the PUE.

The overall carbon footprint of enterprise data center use is related to energy efficiency, but not synonymous with that concept. Sourcing energy from "greener" sources or carbon-neutral power plants contributes to lowering carbon footprints, but doesn't necessarily indicate that operations within the data center are energy efficient. Conversely, a data center can be extremely energy efficient in its operations and still have a relatively large carbon footprint if the energy source is from a power plant burning carbon-intensive fossil fuels.

While improving PUE can help to improve the overall carbon footprint, the most direct carbon reductions can be achieved by choosing renewable power sources. When renewable power sources are chosen as the primary source, the focus changes from PUE to improving computational efficiencies to reduce the carbon impact associated with the computational equipment itself.

PROOF OF CONCEPT - INSIGHTS

Verne Global Insights

Verne Global apportioned CO_2 emissions across its data center customers by measuring IT energy consumption and calculating customer PUE. Total energy is applied to the CEF in order to attain total carbon. This technique provided further insight into the expectations of the ODCA usage model.

Two important metrics for calculating the carbon footprint are transmission efficiency and utility carbon efficiency. Both of these numbers are available, but are calculated annually and in arrears. While these numbers do not tend to vary greatly year to year, Verne Global uses them not as actual values, but as approximations. In a true billing scenario, when actual values become available annually, the billing figures can be adjusted from the approximations to the actual figures.

In general, Verne Global has been pleased with the level of detail provided by Iceland power enterprises, which has supported the demonstration of total carbon utilization and efficiency. They also noted that the lack of real-time information presents an opportunity for improvement.

Verne Global emphasized the importance of carefully selecting metering points to ensure that accurate information is used to calculate the carbon footprint. Accurately allocating PUE to individual customers requires detailed metering information and a good understanding of the overall system design. This challenge could be lessened by encouraging power utility companies to provide access to real-time carbon emission data.

As worldwide regulations increasingly move toward carbon taxation, enterprises can prepare by selecting vendors that incorporate best practices for calculating and reporting on carbon footprint. With proper reporting, customers can effectively justify their support for green computing, while taking into account the financial impacts for their efforts.

The Landsvirkjun report[25] provides a level of detail that is taken into account in the calculation of carbon output. Carbon output is considered for both naturally occurring offgassing that occurs in the geothermal fields, as well as the offgassing associated with vegetation under the hydro reservoirs. It is confirmed that further reductions can be made beyond the very minimal carbon impacts through the purchase of guarantee-of-origin certificates that ensure that generation occurs through hydro sources.

Iceland's power transmission grid was designed and built to accommodate heavy industry. Currently, heavy industry, primarily the aluminium industry, uses 85 percent of the 2.5 gigawatts of generation capacity on the transmission system. Aluminium smelting is an extremely power-intensive industry with single facilities that use 200, 300, and even 500 megawatts of power from Iceland's renewably generated power grid. In Iceland, aluminium smelting facilities do not have engine generator backup; they rely completely on the integrity of the Iceland transmission system. They operate their facilities in this manner despite the fact that after an outage lasting as little as 2 hours, an aluminium smelting facility can begin to incur irreversible damage to the smelting pots. Iceland's transmission company has limited the risk of the heavy industry operators

[25] Landsvirkjun Annual Report 2012. www.landsvirkjun.com/Media/Annual_report_2012.pdf

by installing a ringed transmission system that is able to minimize the amount of time required for the system to heal itself after a power-quality disturbance.

Verne Global taps into this resilient transmission network with an onsite, dedicated substation that is operated by the Icelandic national transmission operated and fully monitored by the onsite 24x7 staff. This substation is the cornerstone of the resilient electrical system that Verne provides to the customers on its campus. Verne Global hosts its customers within a secured, 45-acre campus on a former NATO air base that was operated by the Allied Command. In addition to the 100-percent renewable energy sources offered to its customers—hydro, geothermal, and wind—Verne Global has taken further measures to ensure power resiliency by offering optional power backup with redundant backup from diesel engine generators.

"In instances where the energy comes from multiple sources, calculating the carbon emissions becomes much more complex. The portfolio of power sources must be broken down by the number of kilowatt hours generated and the carbon efficiencies for each individual source."

—Tate Cantrell, CTO, Verne Global

Verne Global achieved lower PUE values in the data center through a design that incorporates free cooling. However, the source of power was more important in determining the location than the PUE itself. Verne Global also focuses on minimizing required mechanical equipment, which reduces both initial and ongoing costs for customers. Energy efficiency was further improved by employing energy-efficient motors in all mechanical systems.

While the importance of improving energy efficiency within the data center is noted, Verne Global believes the most important factor is to select renewable power sources. Additionally, true business sustainability requires that those renewable sources be procured in such a way that allows them to be dependably priced over the long term.

In locations outside of Iceland, Verne Global often works with energy brokers to increase the makeup of the energy derived from renewable sources, favoring wind farms, solar installations, and hydroelectric plants, even in cases where that energy might be somewhat more expensive.

Datapipe Insights

Driven by a strong customer preference for purchasing low-carbon cloud services, Datapipe has initiated an internal mandate to measure and quantify—customer by customer—the carbon footprint of delivering their services. The objective is to give customers tangible, standardized data to bring to the decision makers and governing boards in their organizations, in respect to the relative carbon emissions per unit of measure. Participation in this PoC was seen as a way to accomplish that end, and the test results have advanced this goal and validated the approach.

Cloud providers can reduce carbon footprints by doing the following:

- Locate their services in data centers with a demonstrated commitment to energy efficiency and low-carbon operations, giving preference to centers that use practices that lower PUE values.
- Consolidate applications and virtualizing servers.
- Rely on sensor networks and monitoring to measure airflow and temperatures in and around server racks, using this data to better manage cooling and increase efficiency.
- Monitor and control humidification levels to achieve a balance between server temperatures and efficient operation.

"This PoC establishes a scalable standard of measurement for both the energy efficiency and carbon footprint of cloud computing infrastructure. In conjunction with cost, performance, and geographic location, it is now possible for carbon footprints to take a more prominent role in the IT decision making process."

—Michael Parks, CTO, Datapipe

BMW Group Insights

With an increased emphasis today on enterprises conducting business in a sustainable manner and reporting transparently on their business operations, this PoC demonstrates techniques for enterprises presenting their carbon footprint impact to the public, shareholders, and regulatory bodies.

> "From the standpoint of BMW, the proof-of-concept testing confirmed that equitable comparisons of an enterprise's carbon footprint can be successfully obtained at a cloud-subscriber level. The documented techniques and approach in the ODCA carbon footprint PoC should provide a valuable framework for other organizations to track, measure, and report the carbon emissions linked to their data center activities."
>
> *—Susanne Obermeier, Global Data Center Manager, BMW Group*

By applying the standard units of measurements proposed by the ODCA, following the requirements outlined in the ODCA Usage Model: Carbon Footprint and Energy Efficiency Rev. 2.0,[26] and applying the insights gained from this PoC, organizations can better provide accurate accounting of the impact of their carbon footprint. This is in keeping with the increased expectancy that enterprises be good corporate citizens and include corporate social responsibility (CSR) or triple bottom line reporting (reporting on financial, social, and environmental performance) in annual reports.

Cloud subscribers can progress in reducing their carbon footprint by doing the following:

- Select a cloud provider based on its service location and its access to low emission energy, plus high-energy usage effectiveness (a low PUE value).
- If workloads tend to permit batch processing and latency isn't a critical issue, choose a cloud provider that might be farther away, but that relies on greener, low-carbon energy sources.
- Minimize the use of dedicated hardware and instead aim to maximize the sharing of servers and storage, subject to each organization's security policies.
- Consolidate applications to minimize the number of servers required, subject to security and business recovery requirements. If procuring SaaS, determine the effectiveness of this consolidation.
- Design applications for a cloud environment. Develop and test applications for efficiency of code (code that is more efficient typically uses less compute and storage power). As with application consolidation, determine the effectiveness of the application design for cloud deployment.
- Minimize the amount of data collected and stored to just what is needed to accomplish the mission.

Enterprises understandably often focus on the cost savings of energy efficiency, while regulatory bodies are more concerned with the impact of carbon emissions. As regulatory mandates involving carbon emissions become more rigorous in different regions, data center costs are likely to rise for the least-efficient facilities, driven by carbon taxes, penalties, fines, and carbon trading expenses. This represents another reason why cloud subscribers should seek out the most energy efficient, least carbon-intensive operations to obtain services.

Recommendations

Based on the information provided in the ODCA Usage Model: Carbon Footprint and Energy Efficiency Rev. 2.0[27] and the results presented in this PoC, enterprises have available a number of potential ways to help reduce the carbon footprint associated with cloud services.

Demonstrated techniques for reducing the carbon footprint associated with cloud services include the following:

- Select a "green" data center operator that sources power from a verified low-carbon power plant. As a cloud service provider or cloud service subscriber, this is the single most effective way to ensure a low carbon footprint—whether delivering services to customers or consuming services that are available through the cloud. While the extremely low carbon emissions of the hydro and geothermal power sources that Verne Global relies on, documented in this PoC, cannot be achieved at every location, enterprises can proactively research and select data centers that demonstrate a commitment to low-carbon power sourcing. The ODCA recommends that this information be available within the service catalog of a cloud service provider.
- Choose efficient data centers and cloud providers working together to lower PUE values and continuously move toward enhanced energy efficiency. Where data center power sources are roughly similar in terms of carbon emissions, select a data center or cloud provider that has a lower PUE value, which indicates a higher degree of energy efficiency. Better energy efficiency also lowers the business costs of obtaining cloud services as less electricity use means lower operating and subscription costs.

[26] See www.opendatacenteralliance.org/library
[27] See www.opendatacenteralliance.org/library

- Require real-time carbon data from utilities (rather than annualized information received after the fact), as well as information on the sources of energy and how it is produced, to provide a more accurate picture to purchasers and consumers of the carbon footprint of cloud services. The objective is to allow those who purchase cloud services a standardized way to assess both the cost and the cloud footprint of purchased services.
- Establish standards that provide a genuine comparison of service providers. This approach includes consistently defining the capacity and workloads being purchased and how long these workloads are using the cloud service. Factors to quantify include the relative size of the computing equipment (in defined units, such as small, medium, large) and the duration of services (hours of service at a specific workload level per day or month).
- Make measurements relevant to the customer, as business metrics that make sense. For example, carbon emissions related to business transactions, patterns of workloads, and service consumption metrics based on time and amount.
- Minimize dedicated hardware use. Use shared servers and storage wherever possible, and consolidate applications in a finely tuned virtualized environment for the most efficient server use. In SaaS instances, ask the cloud provider for information about its effectiveness in application design for the cloud.
- Develop "tight" code and minimize storage requirements: Use efficient coding practices and collect and store only the data that is absolutely required to accomplish the mission. Reducing compute cycles and lowering storage needs minimizes energy use by as much as 40 percent, according to a study conducted by Hewlett Packard and the Rocky Mountain Institute.[28]
- Establish optimized business processes (as described in the following section that discusses eBay's Digital Service Efficiency methodology) that add to the efficiency of the technical infrastructure, algorithm efficiency, and other factors that enhance the overall efficiency of delivering cloud services.
- Select equipment that is more efficient, giving more performance for the power consumed or just using less power; for example, as measured in SPEC/watt.
- Use equipment less frequently or use it more efficiently.
- Manage equipment more efficiently; for example, switching it off when it is not being actively used (from "always on" to "always available").
- Use "greener" electricity, usually accomplished by buying it from low-carbon, renewable sources.
- Understanding embedded carbon is also necessary to obtain a complete picture of the carbon footprint of an enterprise. This includes cradle-to-grave or cradle-to-cradle (in instances where significant component recycling is employed), carbon associated with compute workloads, and EDE values. Due to the unavailability of data for these factors prior to the release of this publication, embedded carbon was not included as a part of this PoC.

> "Cloud service providers and the industry should give customers a transparent and clear idea of what they are buying, as well as its environmental impact, energy, and carbon efficiency."
>
> *—Pankaj Fichadia, Chair, ODCA Regulation and Ecosystem Workgroup*

Envision a long-term trends analysis through the following:

- While the PoC measured carbon emissions across a 30-day period, it is envisaged that simpler techniques that can support the analysis of long-term trends of carbon emissions from a cloud subscriber perspective. This analysis is dependent on creating mechanisms to summarize actual carbon emissions that can be accessed by cloud customers through a self-service portal or as figures included on their monthly bill. This capability would support trends analysis and the ability to compare emission levels with other cloud providers, across time periods from same provider, or between internal IT services and cloud-based IT services.

Further details and recommendations can be found in the ODCA Usage Model: Carbon Footprint and Energy Efficiency Rev. 2.0.[29]

[28] Rocky Mountain Institute, Energy inefficiency in a conventional data center. www.rmi.org/RFGraph-energy_inefficiency_in_conventional_data_center
[29] See www.opendatacenteralliance.org/library

Reference to Digital Service Efficiency Metrics

In order to gain a more accurate picture of the cost of delivering services to customers, eBay developed a standardized measurement methodology—digital service efficiency (DSE)[30]—that calculates the cost, performance, and environmental impact of individual transactions. Using this approach, eBay can optimize its technical infrastructure for balanced performance at given workloads to deliver the highest level of service at the lowest environmental impact. The results of this project have been published in a solution brief, "Digital Service Efficiency,"[31] released in March 2013.

The methodology goes beyond PUE measurements, which focus on the energy consumed in powering and cooling the data center, to identify software inefficiencies, the energy efficiency of servers and network equipment, and other factors that contribute to energy consumption as a part of data center operations—ranging from the energy source and continuing downstream to the billions of compute operations at the application level, as shown in Figure 5.

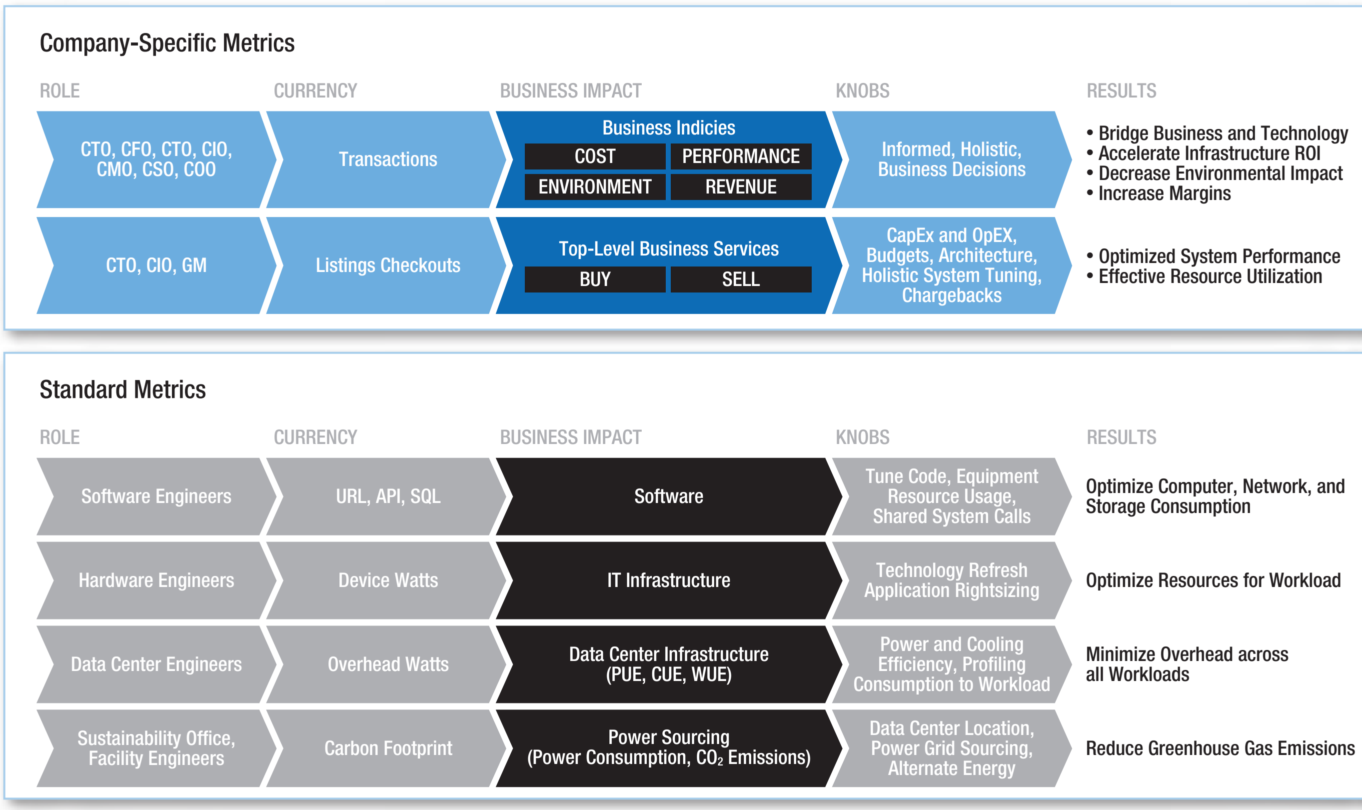

Figure 5. Layers in the digital service efficiency model.

In this manner, DSE can provide a mechanism to assess business value across each of the layers of the technology stack, giving enterprises a means to identify and reduce inefficiencies wherever they are present.

The dashboard eBay developed for DSE tracking provides a precise accounting of buy-and-sell transactions in relation to energy consumption, allowing real-time cost/benefit analyses to guide decision making for site operations and to balance costs, performance, and carbon footprint values. As a representative example, in one quarter in 2012, eBay calculated that their site averaged 45,882 transactions per kilowatt hour.

The ODCA encourages the industry to define carbon usage metrics that relate to business use of cloud computing, using a language and metric that makes business sense.

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[30] Digital Service Efficiency is a measurement methodology developed by eBay to evaluate, tune, and balance technical infrastructure investments. See http://tech.ebay.com/sites/default/files/eBay-DSE-130523.pdf

[31] www.ebaytechblog.com/wp-content/uploads/2013/03/FINAL_DSE-Solution-Paper.pdf

CONCLUSION

The results of testing done for this PoC offer a somewhat idealized picture of a typical data center carbon footprint, based as they are on a model that exists in Iceland, where renewable energy sources drop the carbon emissions to close to zero and cooling is essentially free 365 days a year. These conditions can't be replicated easily in other localities. Many data centers reside in areas where a mix of power sources are accessed on a variable basis and cooling is required on a daily basis, sometimes representing 33 percent of the data center energy use.

The validity of the methods employed in the PoC, however, isn't in question and the overall goal—refining and standardizing the industry-wide approach to expressing and comparing data center carbon footprints—has been advanced by carrying out these test sequences.

The key points that emerge from this exercise are the following:

- The PoC clarifies the concepts and requirements promoted by the ODCA and drives standards for the unified measurement of cloud service providers' carbon emissions.
- The PoC and ODCA's usage model helps enterprises demonstrate progress on green and energy efficiency initiatives. Business value accrues from measuring how green service offerings are, making these concepts tangible for customers, and providing information about cloud-computing workloads that are consistent and understandable for customers.
- Standardized information, as described in this PoC, makes it possible to move beyond the basic PUE values of a data center to a wider range of finite and relevant details for cloud customers—based on workloads, services, and utilization.

Ultimately, the Information and Communications Technology industry should invest in defining standard terms for quantification of carbon usage, such as the ODCA standard units of measure and service catalog. Carbon footprints should be a required data element included in a service catalog, providing a way to help compare service providers through a consistent set of measurement standards.

"From an enterprise customer perspective, this proof of concept demonstrated transparency and rigor in measuring, analyzing, and monitoring carbon emissions for cloud workloads, specified within the ODCA usage model. We need to encourage industry standards and practices to embed these requirements within the cloud lifecycle and ultimately provide a transparent and clear view of the carbon impact of cloud services to the end customer. This leads to improved decision making within business usage metrics, procurement considerations, and efficiency in computing."

—Pankaj Fichadia, Chair, ODCA Regulation and Ecosystem Workgroup

RESOURCES

For more information, refer to the following resources:

- eBay solution brief, "Digital Service Efficiency" (March 2013). www.ebaytechblog.com/wp-content/uploads/2013/03/FINAL_DSE-Solution-Paper.pdf
- The Green Grid, Climate Savers white paper, "Energy Efficiency Guide for Networking Devices" (December 2011). www.thegreengrid.org/Global/Content/csci-white-papers/CSCIWhitePaperEnergyEfficiencyGuideForNetworkingDevices
- The Green Grid, white paper #53, "Electronics Disposal Efficiency (EDE): An IT Recycling Metric for Enterprises and Data Centers" (2012). www.thegreengrid.org/en/Global/Content/white-papers/WP53-ElectronicsDisposalEfficiencyAnItRecyclingMetricforEnterprisesandDataCenters
- U.S. Department of Energy, "Best Practices Guide for Energy-Efficient Data Center Design" (Revised March 2011). www.eere.energy.gov/femp/pdfs/eedatacenterbestpractices.pdf
- Open Data Center Alliance Usage Model: Standard Units of Measure for IaaS Rev 1.1. www.opendatacenteralliance.org/library.
- Open Data Center Alliance Usage Model: Carbon Footprint and Energy Efficiency Rev. 2.0. www.opendatacenteralliance.org/library.

Participants' Sites

- BMW Group - Group-Wide Environmental Protection
- Datapipe - Stratosphere® Green Cloud
- Verne Global - 100% Renewable Energy

