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ABSTRACT

Advances in information technology (IT) have provided a continuous and reliable connection to the Internet for everyone. This factor, coupled with the widespread use of digital devices like laptops, cellphones and tablets, have led to the emergence of "big data". Nowadays, society is producing and using data at an unprecedented rate. Data centers are the primary place for storing, and processing data. Another important trend in IT is the emergence of cloud technology. The rapid rise of IT, the emergence of big data, and the shift to cloud technology have led to a high demand for newer and larger data centers.

Data centers are industrial facilities that provide space for servers, hard drives, and batteries, where data is stored and processed. Having numerous servers that consume large quantities of energy makes heat management a critical issue. Heat, generated mostly by servers, needs to be controlled carefully and temperature needs to be maintained within a specified range. Removing excess heat means extensive use of energy resources by the HVAC systems. This constant high-cooling demand marks data centers as buildings that are especially problematic from an environmental standpoint. The LEED version 4 (v4) rating system now has a category for data centers. However, a review of LEED v4 reveals that it fails to address many sustainability factors related to data centers. By focusing only on specific issues, LEED attempts to make significant improvements to sustainability measures mainly in the sections of Energy and Atmosphere and Indoor Environmental Quality. In other sections of LEED, such as Water and Site Selection, points are not allocated to specifically address data centers' needs. In LEED v4, data centers have the same criteria as other building types. This paper identifies the potential areas for improvement in LEED v4 for data centers.

INTRODUCTION

Data Centers (DCs) have become an essential part of our world. Online file sharing services, like Dropbox and Box, online streaming services, like Amazon Prime, Hulu, and Netflix, and cloud computing services like Elastic Compute Cloud (EC2), all rely on cloud. More IT companies and services utilize the cloud than ever before. One reason for moving to cloud services is the rapid growth in the information technology (IT) industry that has led to ever-increasing use of smart devices, such as tablets, phones and watches. Another reason for the emergence of cloud is the rise of big data. Now, more than ever, companies are in the business of analyzing big data. Big data analysis creates an enormous computational load that requires massive processing capabilities. This, in turn, requires large DCs equipped with extensive racks of servers, storage devices, power supplies and backup lines. It is estimated that there are more than 8.6 million DCs in the world. In 2013, DCs accounted for approximately 1.58 billion square feet of building space worldwide. This number is expected to grow to 1.94 billion square feet by 2018 (Data Center Dynamics, 2014). The unusually enormous reliance on DCs resulted in a substantial rise in DC electricity consumption over the past decade. According to the Department of Energy (DoE), between 2001 and 2006 DC electricity consumption doubled, climbing from 30 to 60 billion kWh (Mashable, 2014). Current annual electricity consumption of DCs is estimated to be around 70 Billion kWh per year, which roughly accounts for 2% of annual United States (US) electricity consumption, and it is predicted to grow at a moderate rate. The resource-intensive nature of DCs and climate-change awareness among top executives have pushed the IT industry towards building and operating green DCs.

In the US, there are around 3 million data centers, which account for roughly 2% of all US electricity consumption. Construction companies have constantly been asked to build new and ever larger DCs. Some estimates show that in 2015 alone the revenue generated from DC development projects was around or above US$500 million, for a handful of construction companies in the US (Bdcnetwork, 2016). In the design sector, it is estimated that in 2014, the revenue generated from designing DCs for at least four design firms was above US$10 million (Bdcnetwork, 2015). In a recent analysis of the DC construction market, the growth of market in 2017 – 2021 period is estimated as a Compound Annual Growth Rate (CAGR) of 6.34%, surpassing the formerly predicted CAGR of 4.18% for the period of 2014 – 2019 (Research and Markets, 2017). These estimates show the favorable DC construction market for construction companies. The recent demand for building green DCs has resulted in more US Green Building Council (USGBC) Leadership in Energy and Environmental Design (LEED) certified DC projects. However, this trend comes with many challenges, not only for the construction industry, but also for the LEED certification program. A brief review of recently developed green DCs reveals that the collaboration between the IT industry and construction companies in building projects leads to innovative green design, construction, and operation strategies that are far more advanced than the green strategies required, or suggested, by LEED. Also, LEED treats DCs the same as other building types despite their unique energy-intensive nature. LEED does not address many important green aspects of DCs construction such as cabling, energy re-use strategies, and energy management. The objectives of this comparative study are to: (1) review LEED v4 for Building Design and Construction of Data Centers (LEED BD+C: Data Centers); (2) study the cutting-edge green design and construction strategies used in newly developed DCs around the world; and, (3) discuss the green elements that LEED needs to address in order to remain as a valuable green certification program in green DCs market. It is worth noting that by word "green" this paper refers to different sustainability aspects in building and operating data centers.

WHY GREEN DATA CENTERS?

A recent survey by Data Center Knowledge (2016) found that around 70% of retail colocation and whole-sale DC services customers consider sustainability in selecting DC providers. The higher cost of using green DCs was the main downgrading factor in the green DC business. However, in the last few years the premiums that green DC users pay compare to traditional DCs has dropped drastically. This factor plays a crucial role in the recent increase in interest in green DCs among DC customers (Data Center Knowledge, 2016). Another factor that contributes to the move towards developing green DCs is climate-change awareness among IT industry companies (Guardian, 2014). Many IT companies commit to carbon neutrality. These companies commit to buy electricity from renewable sources. When using renewable energy sources is not an option, they off-set their use of non-renewable energy sources by buying renewable energy credits. As the United States Environmental Protection Agency (EPA) reported in 2017, four of the top five green power users in the United States (US) are IT companies, namely, Intel Corporation, Microsoft Corporation, Google Inc., and Apple Inc. (Table 1). The IT industry giants are either the main global DC users or main DC service providers. The commitment to use green energy is so widespread among tech companies that some of them purchase more renewable energy than the company's annual energy consumption. Where a company purchases more green power than it consumes, cases like Netflix, the exceeding power is usually sold to company's partners (EPA, 2017).

Table 1. Top IT Companies Performance in Using Green Power (EPA, 2017).

Rank	Company	Annual Green Power (GP) Usage (kWh)	GP% of Total Electricity Use
1 (National)	Intel Corp.	3,429,956,843	100%
2 (National)	Microsoft Corp.	3,344,727,000	100%
3 (National)	Google, Inc.	1,763,588,904	47%
5 (National)	Apple, Inc.	1,173,352,630	100%
70 (National)	Netflix, Inc.	100,057,534	298%
27 (Top 30 Tech)	Green House Data	15,675,000	120%
28 (Top 30 Tech)	Acer America Corp.	15,000,000	104%
29 (Top 30 Tech)	Advantest America, Inc.	9,200,000	101%

While, in terms of building footprint, DCs contribute to a small share of the construction industry, in terms of electricity consumption, DCs account for 2% of annual US electricity consumption. This fact, makes design and construction of DCs a critical factor that can significantly contribute to saving energy on national level. The electricity consumed by DCs was doubled from 2001 to 2006, when the industry experienced a period of high peak. During this period, annual electricity consumption of DCs, in national level, jumped from 30 billion kWh to 60 billion kWh. This peak in DC energy consumption brought law makers, IT industry leaders and governmental agencies, such as the US Department of Energy (DoE), to action to stop this energy consumption growth.

The US DoE believes that "Data centers offer a tremendous opportunity for energy and cost savings". It further argues that by implementing best energy management practices and energy efficiency measures and strategies, it is possible to reduce DC energy consumption by 20% to 40% (DoE, 2017a). Significant research has been undertaken to study the current trends and predict the future of electricity consumption by DCs (Shehabi et al., 2016; Koomey, 2011). It is believed that the electricity consumption of DCs is going to rise at a steady rate in future. It is predicted that annual electricity consumption of DCs will not surpass a maximum of 73 billion kWh by 2020. Table 2 illustrates the electricity consumption of DCs, its share of national electricity consumption, and its share of the retail sale of electricity in the US from 2014 to 2016. It can be seen from this table that, in 2016, DCs accounted for 70 billion kWh electricity consumption in the US.

Table 2. Data Centers Electricity Consumption in the US in billion kWh (EIA, n.d.; Statista, 2017; Shehabi et al., 2016).

Year	Total Electricity (E) Consumption (C)	Retail Sales of E	Data Center (DCs) EC	Contribution of DCs EC to E Retail Sales	Contribution of DCs EC to Total EC
2014	3,903	3,765	70	1.86%	1.79%
2015	3,900	3,759	70< <73	1.86%< <1.94%	1.79%< <1.87%
2016	3,853	3,711	70< <73	1.89%< <1.97%	1.81%< <1.89%

Companies such as Equinix, one of the two world leading companies in the DC business, reported consumption of 2600 GWh of electricity in 2015, equivalent to 239,000 average U.S. residential homes. The energy sources of electricity consumed in the whole continent of America were: 19% renewable, 21% coal, 25% natural gas, and 25% nuclear (Equinix, n.d.b). This shows the energy intensive nature of DCs and the role they play in carbon generation. Energy is not the only environmental concern in the design and construction of DCs. Extensive use of cables, water for cooling purposes, pipes, and batteries pose serious environmental questions for the construction process of DCs. As an example, in a recently built DC, developed by Mortenson company, more than 185 km (608000 feet) of wires, 1200 meters (4190 feet) of mechanical pipes, 56 km of conduit (35.2 miles), and battery plant sufficient for 5120 hours of power were used. Security and resiliency are other factors that are related to sustainability. In the aforementioned DC, the Mortenson company integrated resiliency in the design and construction of the DC, as this DC building can resist 185 mph winds (Mortenson, 2017).

DATA CENTERS IN LEED V4

LEED is a green building certification program developed by the USGBC that certifies different types of buildings based on their performance with respect to sustainability measures. It is the most prominent green building certification system in the US and certifies more than 204,000 square meters (2.2 million square feet) of buildings daily (USGBC, n.d.). The LEED system has been criticized by many scholars over many different issues (Scofield, 2013; Scofield, 2009; Matisoff et al., 2014). This research is not concerned with discussing the advantages and disadvantages of LEED but with LEED green measures for DCs. LEED established a set of baselines which are believed to enhance construction design and process in terms of green measures. This paper does not present a detailed overview of different components of LEED; instead it clarifies how different DCs are treated compared to other building types by showing the differences in LEED points and prerequisites awarded to DCs versus other building types.

Table 3. Distribution of Prerequisites & Credits Dedicated to Data Centers in LEED v4.

Section Name	Total Number of Prerequisite & Credit *Categories*	Number & Names of Prerequisites & Credit *Categories* (Partially or Fully) ***Dedicated*** to DCs
Location & Transportation	8	0
Sustainable Sites	13	0
Water Efficiency	7	0
Energy & Atmosphere	11	**4** (Prerequisite: Fundamental Commissioning & Verification Required; Prerequisite: Minimum Energy Performance Required; Credit: Enhanced Commissioning; Credit: Optimize Energy Performance)
Materials & Resources	12	0
Indoor Environmental Quality	12	**2** (Credit: Enhanced Indoor Air Quality Strategies; Credit: Thermal Comfort;
Innovation	2	0
Regional Priority	1	0

LEED: BD+C v4 applies to new construction, core and shell buildings, schools, retail, warehouses and distribution centers, hospitality, healthcare, and DCs. It is comprised of eight main parts: Location & Transportation (LT), Sustainable Sites (SS), Water Efficiency (WE), Energy & Atmosphere (EA), Materials & Resources (MR), Indoor Environmental Quality (EQ), Innovation (IN), and Regional Priority (RP). Each part is divided to different sections including prerequisites and credits. All prerequisites need to be satisfied and a certain number of points need to be achieved in order for a

LEED certification to be awarded. Table 3 shows the number of prerequisites and credits in each section and the ones that are partially or fully designated to DCs. Despite the fact that DCs are a special building type with few human users, and are an extremely energy-intensive building type, not many credits and prerequisites considered these special characteristics in LEED v4. As Table 3 illustrates, in LT, SS, WE, MR, IN and RP there are no dedicated credits or prerequisites for DCs. DCs distinctive characteristics are only partially reflected in EA and EQ. In EA, two prerequisites and two credits are, partially or fully, dedicated to DCs. In EQ, only two credits are designated for DCs. DCs are totally distinct from other building types that LEED were designed for, such as schools, retail, warehouse and distribution centers, hospitality and healthcare buildings. The exclusive characteristics of DCs demand for a unique green building certification system that considers their special characteristics. However, LEED v4 DCs shares 90% of points and prerequisites with other building types.

STATE-OF-THE-ART OF BUILDING GREEN DATA CENTERS vs LEED BD+C: DATA CENTERS

This section presents an overview of the current state-of-the-art of green design and construction technologies and strategies used in building green DCs. DCs are energy-intensive buildings, with very low occupant-to-area ratios; these two factors make them distinct from other building types. No other building type in LEED has the combination of these two characteristics. In order to reduce the amount of energy that DCs are using, many cutting-edge green design and construction strategies are being applied. Since the rise in DC energy consumption in the last 10 years, US DoE has initiated programs encouraging DCs owners to improve energy efficiency. This movement at the Federal level, coupled with some ambitious agendas in the private sector, has halted the previously high rate of DC energy consumption growth (Shehabi et al., 2014).

The main factors that determine the energy efficiency of DCs is measured by its Power Use Effectiveness (PUE). As Equation (1) illustrates, PUE is the ratio of Total Facility Energy to IT Equipment Energy.

$$PUE = Total\ Facility\ Energy / IT\ Equipment\ Energy \quad (1)$$

PUE simply reflects the energy needed for maintaining DCs, as a building, compare to the energy needed for operating the IT equipment. PUE is a good measure for explaining the efficiency of DC buildings in terms of the energy used for operating the building plus the energy used for operating IT services. The cutting-edge PUE in DCs are between 1.1 and 1.5, while many traditionally built DCs maintain a higher PUE of 2 or greater (Shehabi et al., 2014). Many different design and construction strategies have been implemented to achieve lower PUEs. In an effort at the Federal level to increase DC efficiencies, DoE recommends a series of best practices including aisle separation and containment, raising temperature set points, high-efficiency chilled water systems, free cooling, thermal storage, use of waste heat, on-site energy generation, and energy monitoring (Bruschi et al., 2011). The US DoE repeatedly argues that "Inefficiencies in the power and cooling systems of the data center infrastructure often give data center owners and operators significant opportunities for energy-efficiency measures" (DoE, 2017b; Bruschi et al., 2011). In the private sector, companies such as Equinix implemented cutting-edge design strategies to increase DC energy efficiencies including Deep Lake Water Cooling (DLWC), using all Energy Star products, retro-fitting IBXs with compact florescent light bulbs and LED lights, cold aisle containment, and deploying water-side and air-side economizers (Equinix, 2014). It is worth noting that some of these techniques, like DLWC, are truly innovative.

Although energy is the main issue concerning the DoE and DC service providers in terms of sustainability, there are other green measures that private sector and governmental agencies are concerned with. Cabling is one of these issues. Using racks of servers, storage devices and back-up batteries means using long high-quality and expensive cables. The cabling systems often confuse DC operators if they are not properly coded. The Open Computer Project (OCP), an open source collaborative platform for sharing innovative ideas on redesigning hardware technology to efficiently support the demand for IT infrastructure, developed a color-coded scheme for cabling the server, which is believed to improve operational efficiency, reduce cost and reduce training time (Bailey, 2017). While no specific recommendation or requirement have been given to the important issue of water by LEED, in the era of water scarcity, water management raises concerns among many DC owners. Green House Data, a sustainability-pioneer in the DC business, reported that in 2016, the company used 2909930 gallons of water, an increase of over 900000 gallons of water compared to 2015 (Green House Data, 2017). Water is mostly used in HVAC systems to remove the excess heat from DC buildings. The importance of using high efficiency water management systems was also brought up in the 2015 Microsoft Sustainability report. Many cutting-edge techniques have been used by Microsoft in DCs HVAC units to minimize the water usage in DCs (Microsoft, 2015).

The most important factor for selecting the suitable DC site was the proximity to headquarters of the owner or the technical need for DCs in an area, however, remote management tools, and cloud computing infrastructures have changed this pattern. The state-of-the-art DCs can be located in any part of the world to provide cloud computation and processing technologies to customers around the globe. Countries like Iceland took advantage of this fact to couple their climate advantage with tax credits, and low tax rates, in order to host more DCs (Verne Global, 2017b). The location-independency provides a unique opportunity for DC owners to free the high cost of electricity in traditionally DC crowded areas like Silicon Valley (Data Center Knowledge, 2017). DCs generate excessive heat and need to be cooled down constantly. The need for cooling energy can be greatly decreased by intelligently locating DCs in places, like Iceland, that have the geographical advantage of access to free natural cooling. While, taking advantage of a location with natural cooling can play a vital role in decreasing DC energy consumption, LEED does not have any specific credit or prerequisite dedicated to it.

DCs deal with enormous amounts of data that always need to be kept safe. They need to resist any security breach, not only virtual, but also physical. DC buildings need to be able to resist any type of natural disasters. The resiliency concern is taken extremely seriously in the DC industry. Mortenson (2017) recently built a green DC that can resist winds up to 300 kilometers per hour (185 miles per hour). Resiliency in DCs is not only needed in the form of building resiliency but also in the operational phase of DCs. Critical issue of electricity outage and dependency of DCs on power grids is noted in different reports (Verne Global, 2017a). It is reported by many literatures including Raghavendra et al. (2008) and Greenberg et al. (2006) as best practice to use multiple electricity providers to ensure optimal and uninterruptable power supply. While, the importance of resiliency factors in DC construction needs to be taken into account by DC builders, however, LEED is not concerned with DC resiliency at any level.

DISCUSSION AND CONCLUSION

The LEED BD+C: Data Centers treated DCs not as a unique type of building but as one type of building that needs the same sustainability measures as other building types. The LEED v4 for DCs only, partially or fully, specifies dedicated sustainability measures in two areas Energy and Atmosphere, and Indoor Environmental Quality. However, this paper argues that DCs are a unique building type with significant environmental impacts. This unique building type needs special attention in green building certification systems like LEED. Although LEED failed to recognize these differences, the Federal government, DC owners, and operators have made significant contributions to greening DCs in the US, which in some cases go well beyond LEED requirements. While LEED only tries to significantly improve sustainability measures in the Energy and Atmosphere and Indoor Environmental Quality areas of DCs, this research shows that other efforts, led by Federal government and the private sector, have been trying to improve sustainability measures in a variety of other areas including water, security and resiliency, and site selection. Also, IT industry attempts to improve the energy efficiency of DCs surpassed the LEED requirements. LEED only tries to optimize the energy performance of DCs based on a base model. However, DoE, DC designers and owners follow a totally different path by trying to design DCs that operate with minimum energy by restricting the desired PUE. In water, site selection, and security and resiliency outstanding work has been done by DC owners and operators to green the DC industry. But these issues are yet to be addressed in the LEED. While traditional DCs exist as stand-alone buildings, the contemporary view is to build a series of data centers and infrastructure connected together as a campus, which can potentially form DC neighborhoods in future (Digital realty, n.d.). This potential technology-neighborhood, where all required infrastructure is located with direct short access to critical equipment and personnel, is a likely future scenario for the DC industry. Therefore, it is important for any green building certification system to add this issue to its scheme. While LEED for Neighborhood Development was not a very-successful attempt by USGBC LEED to green the residential sector, technology-neighborhoods can bring new challenges to LEED compared to the existing LEED for Neighborhood Development.

It is worth noting that although USGBC LEED was the pioneer in greening DCs in the US, it is not the only organization trying to elevate the design and construction of DCs to a sustainable level. Industry-led consortiums are becoming more prominent in the green DC business. As an example, Green Grid, a consortium of companies, agencies and institutions, formed in 2008, is a collaborative effort between the private sector, governmental agencies, and educational institutions to drive changes in the DC industry. At the governmental level, drivers for change like the USDOE or the

European Union Code of Conduct for Data Centers, is a governmental-led program, partnered with the private sector, to "reduce energy consumption in a cost-effective manner without hampering the critical function of data centers." (Equinix, n.d.a). All these industry-led and federal-led efforts to green DCs threaten the position of construction-led efforts to lead the way to green DCs. USGBC LEED and other green building certification systems aim to retain or include DCs in their certification system, should re-consider their approach to DCs if they plan on being central players in greening DCs.

Viewing DCs as unique structures that are fundamentally different from other building types, requiring DCs to obtain PUEs in the range of existing cutting-edge green DCs, embedding prerequisites and credits for water, and site selection, and also imposing resiliency factors that would specifically meet the needs of DCs are the likely future for any green building certification system that leads to greening DC construction.

REFERENCES

Bailey, M., J. (2017). "Data Center Cable Infrastructure Color Schema" < http://bit.ly/2sSoAVP> (July 6, 2017).

Bdcnetwork. (2015). "DATA CENTER SECTOR GIANTS: Fluor, Gensler, Holder Construction among top data center AEC firms". <http://bit.ly/2svl5FK> (July 2, 2017).

Bdcnetwork. (2016). "Top 40 Data Center Construction Firms". <http://bit.ly/2tvvySC> (July 2, 2017).

Bruschi, J., Rumsey, P., Anliker, R., Chu, L., & Gregson, S. (2011). Best practices guide for energy-efficient data center design. *Rumsey Engineer-National Renewable Energy Laboratory*.

Data Center Dynamics. (2014). "Number of data centers to decrease after 2017" < http://bit.ly/2sCitJq > (July 2, 2017).

Data Center Knowledge. (2017). "Going Green in Silicon Valley is Expensive, but Not for Everyone". < http://bit.ly/2tWCRWF> (July 2, 2017).

Data Center Knowledge. (2016). "How Renewable Energy is Changing the Data Center Market" < http://bit.ly/2baiMn8> (July 2, 2017).

Digital realty. (n.d.). "Connected Campus: The One Solution You Will Ever Need". < http://bit.ly/2tmDjMs (July 3, 2017).

DoE (2017a). "Energy efficiency in data centers" <https://energy.gov/eere/femp/energy-efficiency-data-centers> (July 3, 2017).

DoE. (2017b). "Data Center Metering and Resource Guide" < http://bit.ly/2uPLdfl > (July 6, 2017).

EIA. (n.d.). "Retail sales of electricity, annual" < http://bit.ly/2sLFQ3S> (July 5, 2017).

EPA. (2017). "Green Power Partnership National Top 100" < http://bit.ly/1XzEhuU> (July 3, 2017).

Equinix. (n.d.a). "Energy Management and Environmental Standards". < http://bit.ly/2tvpQjF> (July 2, 2017).

Equinix. (n.d.b). "Green Data Centers". < http://bit.ly/1Hcs64d> (July 2, 2017)

Equinix. (2014). "EQUINIX WORKING TOWARD A SUSTAINABLE FUTURE". <http://bit.ly/2tvii0v> (July 6, 2017).

Green House Data. (2017) “Annual Sustainability Report”. < http://bit.ly/2sVXr4I> (July 7, 2017).

Greenberg, S., Mills, E., Tschudi, B., Rumsey, P., & Myatt, B. (2006). Best practices for data centers: Lessons learned from benchmarking 22 data centers. *Proceedings of the ACEEE Summer Study on Energy Efficiency in Buildings in Asilomar, CA. ACEEE, August 3*, 76-87.

Guardian, (2014). Apple: climate change is real and it's a real problem. <http://bit.ly/2vKGnjm> (August 30, 2017).

Koomey, J. (2011). Growth in data center electricity use 2005 to 2010. *A report by Analytical Press, completed at the request of The New York Times*, *9*.

Mashable. (2014). “There Are Now 3 Million Data Centers in the U.S., and Climbing”. < http://bit.ly/2sLeqLE > (July 3, 2017).

Microsoft. (2015). “Datacenter Sustainability” <http://bit.ly/2sPGGg6> (July 7, 2017).

Matisoff, D. C., Noonan, D. S., & Mazzolini, A. M. (2014). Performance or marketing benefits? The case of LEED certification. *Environmental science & technology*, *48*(3), 2001-2007.

Mortenson. (2017). “THE STREAM PRIVATE DATA CENTER” < http://bit.ly/2uw5PJR> (July 2, 2017).

Raghavendra, R., Ranganathan, P., Talwar, V., Wang, Z., & Zhu, X. (2008, March). No power struggles: Coordinated multi-level power management for the data center. In *ACM SIGARCH Computer Architecture News* (Vol. 36, No. 1, pp. 48-59). ACM.

Research and Markets. (2017). “Data Center Construction Market in the US 2017-2021”. < http://bit.ly/2tvo5D3> (July 2, 2017).

Scofield, J. H. (2009). Do LEED-certified buildings save energy? Not really…. *Energy and Buildings*, *41*(12), 1386-1390.

Scofield, J. H. (2013). Efficacy of LEED-certification in reducing energy consumption and greenhouse gas emission for large New York City office buildings. *Energy and Buildings*, *67*, 517-524.

Shehabi, A., Smith, S., Horner, N., Azevedo, I., Brown, R., Koomey, J., Masanet, E., Sartor, D., Herrlin, M., and Lintner, W. (2016). United States Data Center Energy Usage Report. Technical report, Lawrence Berkeley National Laboratory.

Statista. (2017). “Total electricity end use in the U.S. from 1975 to 2016” < http://bit.ly/2tmhhJA> (July 5, 2017).

Techtarget. (2010). “green data center”. < http://bit.ly/2sLFY3m > (July 2, 2017).

USGBC. (2017). LEED v4 For BUILDING DESIGN AND CONSTRUCTION. < http://bit.ly/2sLH67u > (July 6, 2017).

USGBC. (n.d.). “Better Buildings Are Our Legacy” <https://www.usgbc.org/leed> (July 6, 2017).

Verne Global. (2017a). “Northern lights: Why New York data center operators should consider migrating north”. < http://bit.ly/2tEx8QY > (July 2, 2017).

Verne Global. (2017b). “Why tax matters when it comes to data center site selection”. < http://bit.ly/2rm2qzo > (July 2, 2017).