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Renewable Energy in the Data Center Industry

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EXECUTIVE SUMMARY

According to a recent IEA publication, global data center electricity use in 2020 was 200–250 TWh[1], or around 1% of global final electricity demand. Major builders of data centers are committing to building renewable power generation facilities along with their data centers, lessening the strain on the local utilities while also helping them to meet local, state, and federal requirements for renewable energy production.

This paper explores the short- and long-term ramifications the renewable power source has on the architecture of the power train in the data center.

HISTORICAL TRENDS OF ENERGY CONSUMPTION IN THE U.S.

According to the U.S. Energy Information Administration provided graph (Figure 1), the United States has relied on coal, oil, and natural gas to provide most of the energy consumed since the early 1900s. The oil embargo of the 1970s, the formation of the Environmental Protection Agency (EPA) during the Nixon administration, and the rampant smog pollution from vehicles and coal-fired power plants spurred America to begin weaning itself off oil and coal as the primary fuels for power generation. Coupled with the needs of a growing population, it was essential to start investing in new sources of energy capable of scaling their outputs to match the ever increasing lifestyle and GDP of the country and the rest of the world.

Nuclear energy was once seen as the clear successor to coal for domestic electricity generation in the U.S. Still, a series of mishaps over the years has delayed, perhaps permanently, the widespread adoption of nuclear power. Incidents at Three Mile Island (US), Chernobyl (Ukraine), and Fukushima (Japan) have made it difficult in the minds of many to justify the growth of nuclear power plants as a source of electricity. The waste byproducts of nuclear fission are of concern as well.

Work in the field of space exploration by NASA and other countries' space programs during the 1950s led to the development of the first photovoltaic solar cells capable of turning sunlight into direct current (DC) electricity[2] . When the price of oil skyrocketed in the 1970s and again in the early 2000s, solar power was first considered as a potential alternative to carbon-based energy sources. However, the cost per kWhr has traditionally had difficulty reaching parity with power from coal, oil, and natural gas until recently.

1. https://www.iea.org/reports/data-centres-and-data-transmission-networks

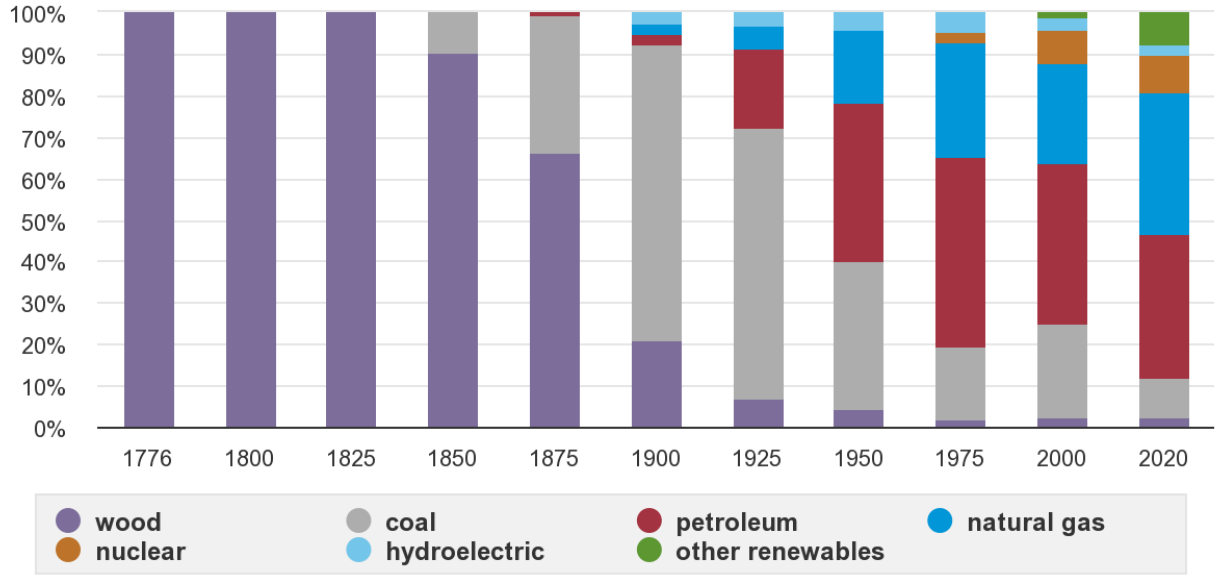
2. https://www.smithsonianmag.com/smart-news/worlds-first-solar-powered-satellite-still-there-after-59-years-180962510/

WHAT IS ENERGY?

The U.S. Energy Information Administration (EIA) defines energy as "the ability to do work. Energy comes in different forms — heat (thermal), light (radiant), motion (kinetic), electrical, chemical, nuclear, and gravitational."[3]

For the purposes of this paper, we are focused on electricity as the primary energy derived from all potential sources.

Shares of total U.S. energy consumption by major sources in selected years (1776-2020)



Source: U.S. Energy Information Administration, *Monthly Energy Review*, Appendix D.1, and Tables 1.1 and 10.1, April 2021, preliminary data for 2020
Note: Wood includes wood and wood waste; other renewables includes biofuels, geothermal, solar, and wind.

Figure 1- US Energy Consumption by Source

3. https://www.eia.gov/energyexplained/index.php?page=about_home

DATA CENTERS AND ELECTRIC POWER CONSUMPTION

Traditionally, data center locations are chosen for their proximity to cheap, reliable AC power from one or more utility provider power sources, coupled with proximity to a fiber link to the backbone of the internet. Ideally two or more utility generation stations could supply power to the data center, providing fully redundant power, and ensuring maximum uptime for mission-critical applications. On-site, diesel-fueled generators were deployed to mitigate the risks of losing all utility-supplied power.

For the most part, an individual data center acts as a relatively stable load on its power utility, consuming vast amounts of alternating current (AC) both night and day. It is not unusual for cloud and hyperscale data centers to be built to continuously consume 40MW or higher. Historically servers, networks, and internal cooling fans are turned on and left on. These then represent a "base" load for the utility and help set the lower limit on what the utility needs to produce at all times. Steady loads allow the utilities to use the cheapest means of production to meet the needs of their customers.

The advent of the now-ubiquitous smartphone, combined with the widespread adoption of digital television and video technologies, has led to the need for a growing number of data centers to store, process, and deliver the immense streams of data continuously flowing around the world. This growth in the number and scale of data centers has strained the power grid at times. With vast numbers of electric cars beginning to replace gasoline- and diesel-powered vehicles, the demand for electric power continues to climb, offsetting many of the reductions resulting from adopting more efficient Energy Star® rated appliances, light bulbs, and HVAC systems. And while data center operators generally negotiate their power costs to avoid "time of day" surcharges, increased electric power consumption has caused them to explore ways to remain profitable as the cost of utility-provided electricity creeps upwards over time. Given the potential for further increases in demand and prices of electricity, forward-looking companies have begun taking responsibility for generating their own power to run their data centers. By doing so, they gain control over their ability to grow without needing to be dependent on taxpayers and the public utilities for powering their data centers.

WHAT IS RENEWABLE ENERGY?

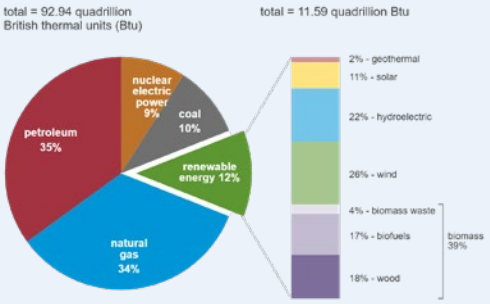
The EIA defines renewable energy as "energy from sources that are naturally replenishing but flow-limited. They are virtually inexhaustible in duration but limited in the amount of energy that is available per unit of time."[4]

The EIA explains that the major types of renewable energy sources are

- Biomass—includes:
  - Wood and wood waste
  - Municipal solid waste
  - Landfill gas and biogas
  - Ethanol
  - Biodiesel
- Hydropower
- Geothermal
- Wind
- Solar

Since 2001, the uptake of renewable energy has seen slow but steady progress. Figure 2 provides a detailed breakout of the types of renewable energy used in 2020, with biomass, hydroelectric, and wind being the top sources.

U.S. PRIMARY ENERGY CONSUMPTION BY ENERGY SOURCE, 2020



Source: U.S. Energy Information Administration, *Monthly Energy Review*, Table 1.3 and 10.1, April 2021, preliminary data
Note: Sum of components may not equal 100% because of independent rounding.

4. https://www.eia.gov/energyexplained/renewable-sources/

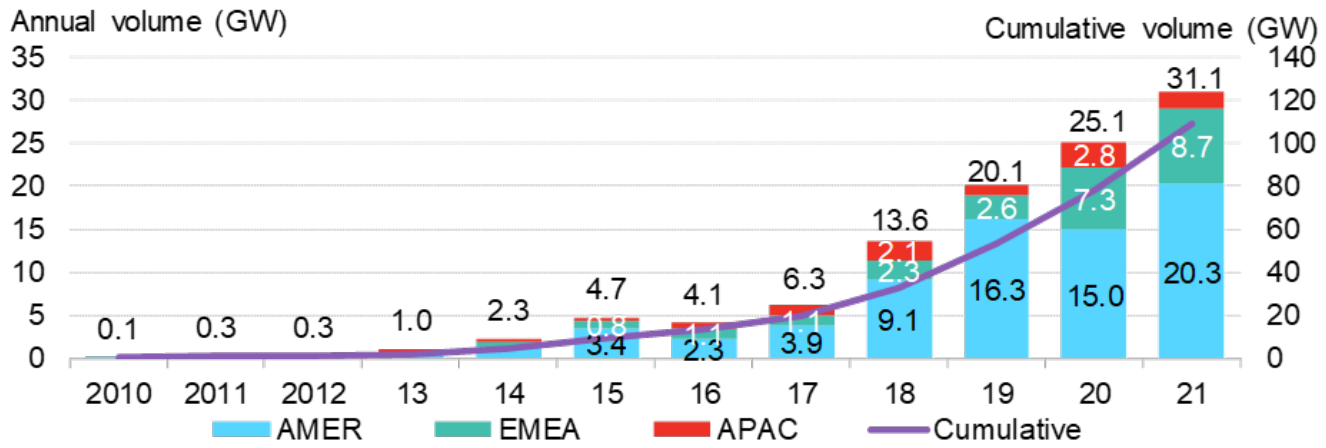


Figure 3 - Global Corporate Power Purchase Agreement (PPA) Volumes, 2010-2021. From BloombergNEF.

WHY ARE DATA CENTERS USING RENEWABLE ENERGY?

Companies such as Apple, Google, Microsoft, Switch, eBay, and Meta (formerly Facebook) have the financial means and intellectual resources to deploy technology in ways unattainable to individual consumers. By using renewable energy sources such as wind, solar, fuel cells, and hydroelectricity to power their data centers, these companies minimize transmission and conversion losses, reduce their perceived carbon footprint, and gain control over their sources of energy production.

Using renewable energy allows them to grow their data centers to meet customer demands while complying with local, state, and federal environmental impact laws. Generating their own power also means that the hyperscale data center builders could potentially not have to rely on the local utilities for their businesses. However, when the data centers build renewable energy production in cooperation with local utilities, they help the utilities meet requirements for growing production from renewables and lessening the dependence on oil, gas, and nuclear power for producing electricity. Working in conjunction with the utilities also allows the data centers to obtain utility power when the renewable source "turns off," such as when the sun goes down, or the wind stops blowing. This scenario represents a "win-win" for both the data centers and the utilities.

By using non-carbon intensive energy sources, these companies can satisfy environmental concerns from Greenpeace and others about the potential impacts that result from increased energy consumption.

HOW RENEWABLE ENERGY IMPACTS DATA CENTER DESIGN: AC VS. DC

For many reasons, the power train supplying a data center has historically been implemented using AC power. From generation to transmission to the point of use, the power has been AC that gets stepped up or stepped down in voltage as needed before being converted to DC power by the silver box power supply residing in a server, network switch, router, load balancer, or storage application.

Many renewable energy sources inherently generate one form of electricity or another. Photovoltaic (PV) solar cells generate DC. Biogas and natural gas-powered fuel cells generate DC. To be used in most data centers, the DC power from solar farms and fuel cells goes through an inversion process that turns DC into AC power. This process allows the electricity to be transmitted efficiently across a distance and put back into "the grid" when not being put into energy storage systems or loads such as data centers.

Over the past decade, several proponents have suggested that DC power coming into the data center could result in a simpler design with fewer conversion steps and fewer conversion losses.[5] The data center market has seen very few facilities go in the direction of a DC infeed and DC bus bars for distributing power to the row. As volumes of PV cells and fuel cells continue to climb, unit costs have come down to the point where generating electricity is near parity with the cost of power coming from the local utilities. This could eventually change the math that dictates the power architecture of the data center. Some Apple data centers have been built on land large enough to incorporate solar PV arrays into their campus, yet they remain designed to take an AC infeed to the building. (Fig. 4)

Figure 4 - Apple Maiden, NC facility

Windmills and hydroelectric turbines generally produce AC power that can go directly into the electric grid. In most cases, data centers are not close enough to the windmill or to the dam supplying the hydroelectric power, requiring the data center to rely on an AC infeed provided by a utility to get the electricity from the point of generation to the point of consumption.

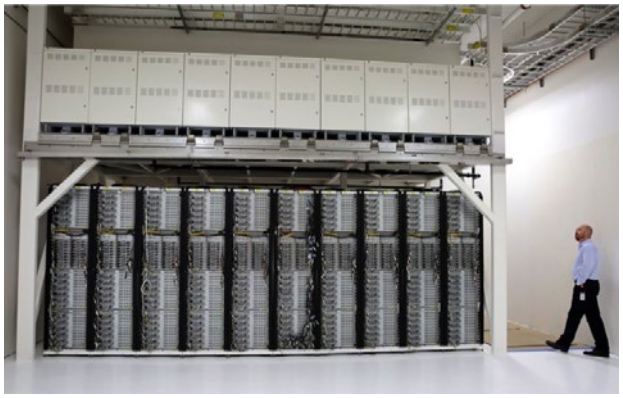


Figure 5 - Microsoft fuel cell on rack experimental data center[6]

Microsoft has been a notable pioneer in rethinking the power train for their data centers. For example, their data center in Cheyenne, WY, is powered by a biogas source supplying fuel cells on-site. More recently, Microsoft built an evaluation lab that brings natural gas to the top of the rack and uses fuel cells located there to convert the gas to DC power that is consumed directly by the devices in the rack. This saves on power transmission losses and conversion losses at the expense of deploying some potentially costly fuel cells. Time will tell if this proves to have the payout Microsoft is hoping for from this experiment. (Fig. 5)

5. https://www.emergealliance.org/

6. https://www.seattletimes.com/business/microsoft/microsoft-makes-a-crazy-bet-on-fuel-cells-to-feed-power-hungry-data-centers/

WHERE ARE WE HEADED?

Renewable energy production and consumption are on the rise for general use and by data centers. The amount of biomass-derived energy in data centers is minuscule but does see some experiments being done to explore feasibility. Microsoft built the first data center running biogas in 2014.[7] Ethanol derived from plants or wood pulp can be used in solid oxide fuel cells (SOFC) as a source for hydrogen. Still, this technology has not yet been widely adopted for data centers.

Bloom Energy SOFC fuel cells running on natural gas dominate in the data center industry. eBay was one of the first to implement the Bloom technology.[8] A detailed write-up of how fuel cells can be used in data centers was published by Microsoft in 2014.[9]

Geothermal energy production occurs in regions where hot springs, geysers, volcanoes, or fumaroles are present. These regions are usually near the boundaries of the earth's tectonic plates.[10] It is not practical to locate a mission-critical data center in these zones, so procuring geothermal energy for data centers relies on the existing utility grids to deliver power from the point of generation to the point of consumption.

Wind and solar are the two renewable energy sources that are likely to dominate the data center industry for the foreseeable future. Wholesale data center builders such as Digital Realty (DLR), colocation operators such as Equinix, and all the major cloud providers (Apple, AWS, Meta, Google, Microsoft, several Chinese firms) are committing to run their entire businesses, not just their data centers, on renewable energy going forward.

META: 100% RENEWABLE ENERGY IN DATA CENTERS BY 2020

In 2020, Meta data centers and operations ran exclusively on energy supplied by renewable sources. Additionally, they have pledged to be carbon neutral by 2030.[11]

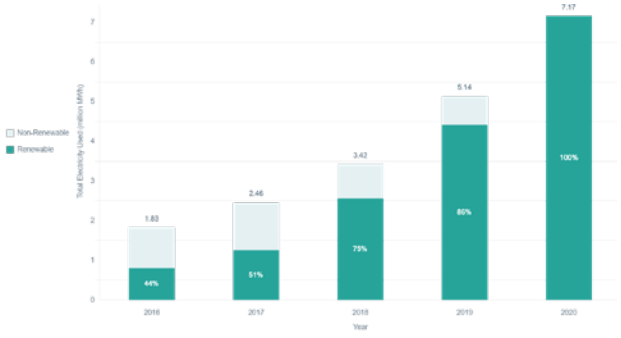


Figure 6 - Meta data center energy sources[12]

7. https://blogs.microsoft.com/green/2014/11/07/microsofts-biogas-powered-data-plant-opens-in-wyoming/
8. https://www.datacenterknowledge.com/archives/2013/10/02/a-closer-look-at-ebays-bloom-powered-data-center
9. https://www.microsoft.com/en-us/research/wp-content/uploads/2016/02/FCDC-TechReport.pdf
10. https://www.eia.gov/energyexplained/index.php?page=geothermal_where
11. https://sustainability.fb.com/report-page/energy/
12. https://www.gstatic.com/gumdrop/sustainability/google-2021-environmental-report.pdf

Figure 7 - Google, Mountain View, CA

GOOGLE: PURCHASING 100% RENEWABLE ENERGY FOR DATA CENTERS AND OFFICES IN 2017

Google's Sustainability Report states "In 2017 Google achieved a great milestone: purchasing 100% renewable energy to match consumption for global operations, including our data centers and offices. Although we have a solar farm on our Belgian data center site, building clean energy sources on data center sites is often not possible. The places with the best renewable power potential are generally not the same places where a data center can most reliably serve its users. And while our data centers operate 24/7, most renewable energy sources don't — yet. So, we need to plug into the electricity grid, which isn't currently very green. That's why we're working to make the electricity supply greener as a whole — not just for us, but for everyone. We've added renewable energy to our communities. We're investing in a brighter future for the whole industry. And we're going beyond investing in renewable energy for our own operations — we want to grow the industry as a whole. Not only have we invested $3 billion in renewable energy projects, but we freely share technology that might help others study and respond to environmental challenges."[13]

MICROSOFT: PURCHASING RENEWABLE ENERGY CREDITS, REDUCING CARBON FOOTPRINT

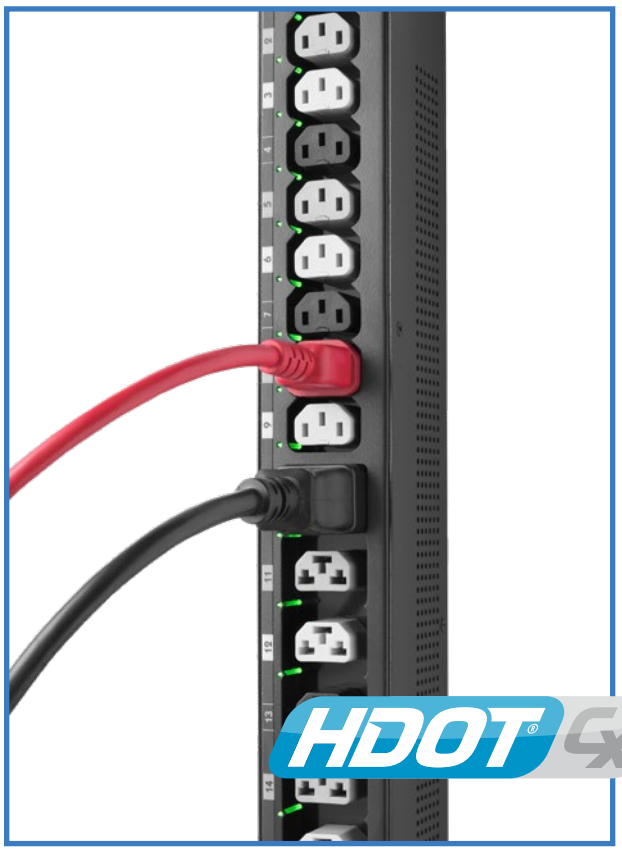
Microsoft is committed to be a carbon negative company by 2030, and by 2050, they are committed to removing their historical emissions since they were founded in 1975. "To achieve this, we are improving efficiency in our operations, devices, and supply chain; we are delivering technology to help our customers measure and manage their carbon emissions more effectively; and we are breaking new ground with carbon removal purchases and investments to help develop the crucial, nascent carbon reduction market. We will help our suppliers, customers, and partners around the world to reduce their carbon footprints through our learnings and with the power of data, AI, and digital technology. By 2025, we expect to power our data centers and facilities with 100 percent additional, new renewable energy generation that matches our electricity consumption on an annual basis."[14] In FY21, Microsoft signed new power purchase agreements (PPAs) for approximately 5.8 gigawatts (GW) of renewable energy across 10 countries around the globe, totaling more than 8 GW of renewable energy via PPAs or long-term contracts.

13. https://www.google.com/about/datacenters/renewable/index.html

14. https://query.prod.cms.rt.microsoft.com/cms/api/am/binary/RE4RwfV

CONCLUSION

The transition to higher adoption of renewable energy production continues for both utilities and consumers, while being led and paid for by the world's largest internet properties. Much of the world is moving towards Net Zero goals between 2030 and 2050. By working with the utility companies to develop sizeable renewable energy production facilities and committing to purchase the outputs, the cloud giants are leading the way to meet the clean energy needs of their data centers, their businesses, and their communities. While the renewable energy (electricity) coming from these projects is a mix of AC and DC power, AC power is the common intermediary that joins the point of production to the utility and on to the point of consumption at the data center. Thus, most enterprise and cloud data centers rely on AC power to run their IT infrastructure.



RACK PDUS FOR AC POWER

Whether your data center is using renewable energy or not, AC power is still the primary infeed to a data center. AC power is distributed within the data center to the IT rack. For those data centers electing to remain with this established approach, an intelligent PDU that supports an infeed of 415VAC 3-phase Wye can deliver 240VAC to the outlet without requiring a transformer in the PDU. This helps to minimize conversion losses, distribution losses, the size of copper cabling needed for power, and enables maximum power density for the rack, resulting in a greener, more efficient data center.

Legrand's Server Technology and Raritan brands of Legrand offer the most comprehensive array of award-winning, highly reliable intelligent (Smart, AKA 'Metered') and managed (Switched) AC power distribution products in the data center industry for 480VAC, 415VAC, and 208VAC power. We offer off-the-shelf, semi-custom, and fully customized AC power distribution solutions suited for your most demanding applications. And we like DC power, too, with rack PDU solutions for systems requiring 380VDC and -48VDC.

RoHS

Energy Savings

WHY SERVER TECHNOLOGY

Server Technology's power strategy experts are trusted to provide rack PDU solutions for demanding data centers worldwide, ranging from small technology startups to Fortune 100 powerhouses. Because power is all we do, you will find us in the best cloud and colocation providers, forward-thinking labs and telecommunications operations. Server Technology customers consistently rank us as providing the highest quality PDUs, the best customer support, and most valuable innovation. Let us show you — we have over 12,000 PDU configurations to fit every need, and over 80% of our PDUs are shipped within ten days.

Only with Server Technology will customers Stay Powered, Be Supported, and Get Ahead.

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To learn more, visit www.Raritan.com

WHY LEGRAND

At Legrand, we build sustainability into everything we do. We are committed to developing solutions that enable high performance buildings (such as data centers), reducing the environmental impact of our own operations and transforming how people live and work — more safely, more comfortably, more efficiently. We were ranked 51st among the Global 100 World's Most Sustainable Corporations in 2018. In addition, Legrand North and Central America was recognized by the Department of Energy (DOE) in 2018 for achieving a 20.3 percent reduction in energy intensity. We are committed to optimizing the way we manage energy, water and waste because these practices are good for the environment and good for business.

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