The Journey to Net Zero Data Centers

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Abstract:

As our dependence and need for more efficient data centers increases, it is imperative that we do not lose sight of the environmental impacts of these facilities. This report analyzes the environmental current state of data centers, along with the practices that can make them more environmentally friendly in order to get closer to the goal of net zero. Some of these practices include recycling materials, using green energy sources, scheduling and load management planning techniques.

Keywords:

Data Center, Cooling, GHG protocol, E-Waste, Renewable Energy

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1 Introduction

Net Zero data centers have emerged as a potential solution to the growing issue of climate change. Putting aside the obvious benefits to the environment, the migration to greener data centers is being driven by government regulations, the court of public opinion, and environmentally conscious shareholders. Big Tech conglomerates have already begun this change, but there are challenges that prevent and arguably even make it impossible to embrace the idea of net zero data centers as a long term solution.

2 Understanding Data Centers and Net Zero

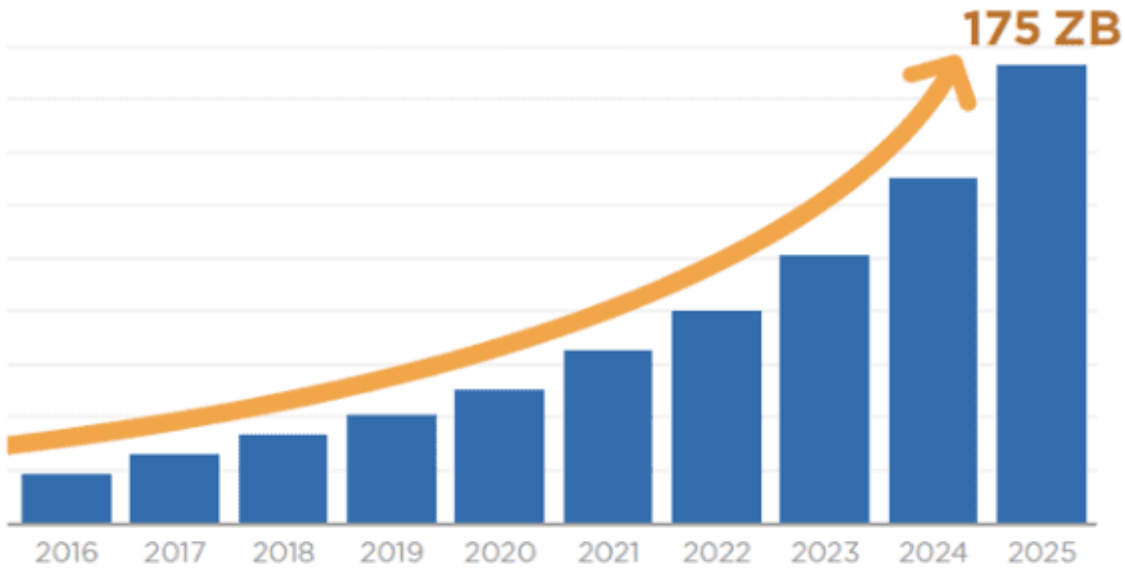
Before we can dive into the why and how to achieve net zero, we need to understand the what. For the purposes of this paper we will use the definition that declares net zero data centers as environmentally sustainable facilities that try to minimize carbon emissions and energy consumption. It is important to note that this definition does not imply "zero carbon emissions," a distinction we will explore in detail later in section 2.3.

2.1 History

The first data center ever built was constructed at the University of Pennsylvania in 1945. It required just 150 kilowatts of power to supply the famous ENIAC[2bm22]. Since 1945, humans have constructed over 8000 data centers with the largest by square footage being Mongolia Information Park with an astonishing size of 10,763,910 square feet. It spans 42 buildings and requires 150 megawatts of power, 1000 times more than the first ENIAC data center[VonHarz23]. As data centers continue to grow, environmentally friendly practices have become more important and standardized.

2.2 Need for Improvements

Over time, humanities annual data creation has only ever grown. By 2025 we are expected to to reach 180 zettabytes(ZB), with a growth rate of 19% each year as shown in Figure 1[ieee23].



IDC says 175 ZB will be created by 2025 (Image courtesy IDC)

Fig. 1: Projected growth of data in the world in ZB[ieee23]

With this increase in data, an increase in the capacity to store it comes hand in hand. Of course, by adding more storage and the ability to manage it, the size of data centers and the power they require has increased as well. Currently data centers operating 24/7 365 are accounting for 3.5% of the total electricity use worldwide[Saur20].

Furthermore, as new devices replace the old, they are often not recycled due to the risk of private data being scraped from the device. For many years, the standard practice has been to incinerate or destroy the devices, leading to an increase in what is called e-waste, or electronic waste. Many of these devices contain hazardous chemicals such as cadmium and lead that when released into the environment have disastrous impacts.

2.3 Net Zero Scopes

The standardized way to measure the environmental success of data centers, along with their companies, is their scope emissions level. These scopes are derived from the Green House Gas(GHG) Protocol, which supplies the world's most widely used greenhouse gas accounting standards[ghgprotocol.org]. In simple terms, scope 1 includes the emissions that are created directly from the company owned resources. Examples of these are air conditioning, lighting and others. Scope 2 emissions are those that are created from the generation of purchased energies by the company. An example of scope 2 emissions is coal emissions created when the company buys

electricity from a power plant. Scope 3 emissions are all other emissions that occur that the company does not have direct control over. Understandably, scope 3 emissions are usually the largest for any company, and also the hardest to reduce since by definition, the company has little to no control over them. In fact, there is much discussion surrounding the very possibility of net zero data centers, since the scope 3 emissions will almost certainly prevent it from happening. Nonetheless, companies have begun to reduce or, even in some cases, eliminate their scope 1 and 2 emissions. For example, Apple Inc. has pushed their scope 2 emissions to 0 by selectively purchasing renewable energy, according to the company's annual ESG(environmental, social and governance) reports[Locke23].

Now that we have covered our goals to have data centers become closer to net zero, and what net zero means, we can discuss how we can achieve that outcome.

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3 The Path to Net Zero Data Centers

There are many ways that Data Centers have been modernized in order to inch closer to the goal of net zero. We start by examining how the role design and infrastructure play in making data centers sustainable. Next, we explore the importance of using green energy sources to power these facilities, which helps reduce their environmental impact. Finally, we consider the regulations and rules that influence how net-zero data centers are built and operated.

3.1 Design and Infrastructure

Starting from the beginning, the construction of data centers is just as important as their long term use. The modern practice of modular design has emerged as an alternative to traditional data centers due to its superior Power Usage Effectiveness(PUE) and Water Usage Effectiveness(WUE), but also for its rapid deployment capabilities and cost-effectiveness[DeltaPowerSolutions23]. Below in figure 2 is an example of a modular data center design as a trailer for transportation.

Fig. 2: A trailered modular data center by IBM[wikipedia23]

Additionally, data centers location can greatly impact the emissions along with the costs. Building close to energy production sources allows for cheaper and more reliable transportation of energies. Some companies even opt for onsite energy, partnering with solar, wind, or hydro generation facilities. In fact, 32% of IT companies said improving the organization's carbon footprint was a reason for new building of data centers[Arcieri22].

Once a data center is built, a large portion of the power required to run it goes toward cooling the many racks of heat producing servers. In fact, the NYT says only 6-12% of power consumption in data centers goes to actual computing, the rest goes to cooling[Lacey14]. This is due to the cooling strategy dating back to the 1970s called "Random Cooling", which subscribes to the belief that "cooling the room cools the devices". However, this has led to increased and unnecessary cooling costs. Utilizing strategies such as rack based air and water cooling can optimize airflow thus making the power we use to cool a facility more efficient[Spinazzola05]. Figure 3 below shows how rack cooling looks in a data center.

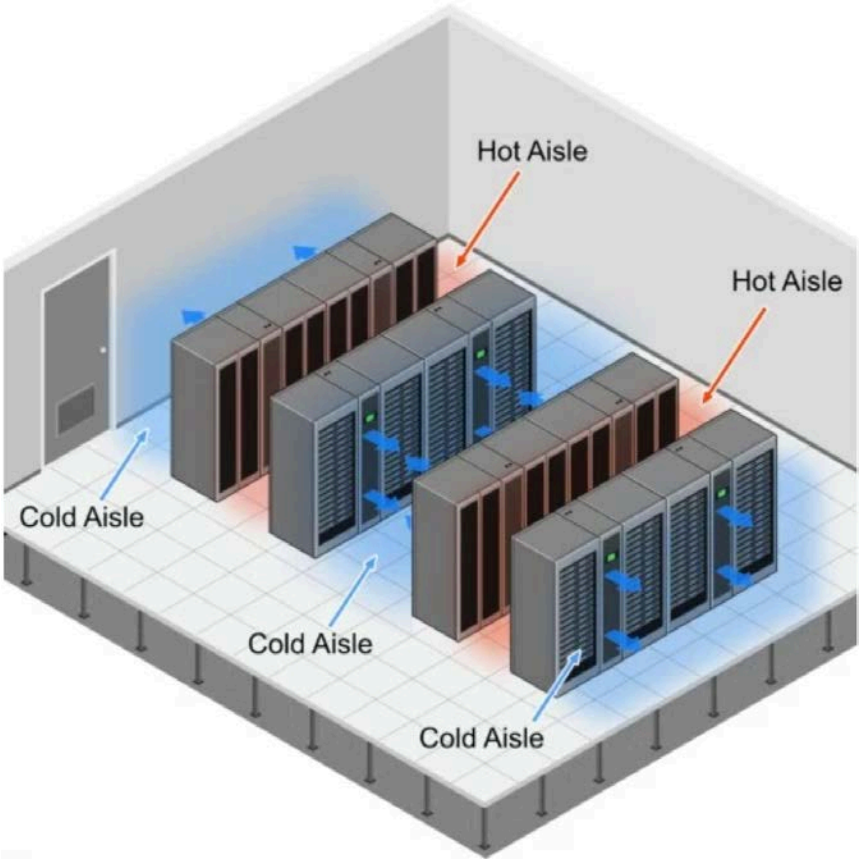

Fig. 3: Implementation of the rack cooling strategy in a data center[Baumann20]

Management and monitoring is also a key factor in data center design. By having edge data centers intelligently communicate with their bridges, we can schedule tasks with delay tolerance, allowing for efficient load management. And since reducing data movement decreases energy consumption, moving domain-specific processing closer to the actual digital storage components using sophisticated management would allow for massive benefits.

Another modern invention that has become popular is the use of so-called Microgrids. A Microgrid is a standalone power grid, independent from the public electricity grid, providing dedicated power for a facility. Along with the reliability they provide, a major benefit is the ability to sell the excess power to other consumers. Below in figure 4 is a block diagram showing the flow of energy in a potential microgrid design

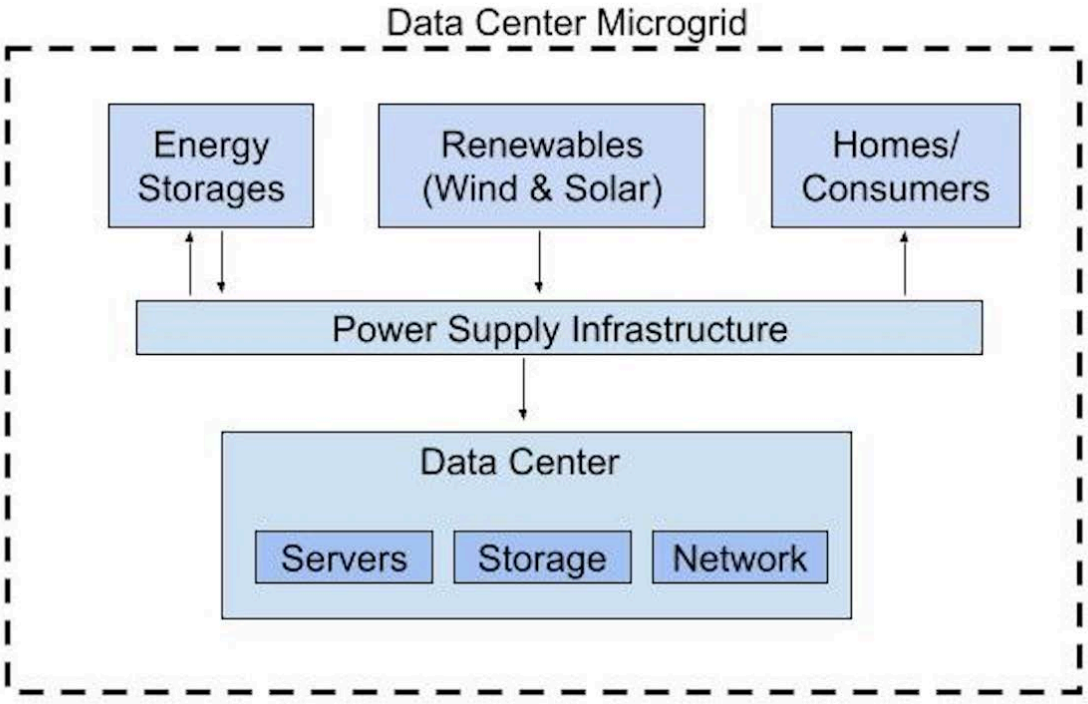

Fig. 4: A diagram showing the flow of energy in a Microgrid[Ding18]

3.2 Renewables

Many strides have been made in this field that previously was unheard of. One key facet involves the frequent upgrades and recycling of data storage devices. Through thorough processes of data sanitization we ensure that older, obsolete hardware doesn't contribute to e-waste and instead the valuable rare earth metals can be recycled into new devices, rather than incinerated. Data centers also use extreme levels of water along with the extreme level of power. Facilities often use both air and water cooling to reduce heat in devices. Ensuring WUE along with PUE during peak service times helps eliminate wasted resources. There are even use cases for extra heat. Facilities in colder climates, such as Finland, have been successfully experimenting with using excess heat to warm homes[Wahlroos18].

3.3 Regulatory

As a growing industry, the government along with several special interest groups have kept a close eye on the rules and regulations surrounding data centers. When the Inflation Reduction Act of

2022 became a law it allowed for tax credits to lower the costs of facilities that used renewable energy[US Dept. Of Treasury23]. However, in order to meet the criteria for the credits, the facilities must be qualified. The Uptime Institute and LEED by the USGBC are a few of the groups that certify the level green facilities. These groups measure data centers environmental performance by their Life Cycle Assessment(LCA) and Green Building Rating Systems (GBRS) among other variables.These ratings have a direct impact on the companies profit, and therefore are a driving factor in the industry pushing towards net zero emissions.

3.4 Public Opinion

Shareholders along with the general public are pushing for greener initiatives across all industries and data centers are no different. The public wants to know what is being done to ensure that the infrastructure in place is meant to last but also meant to be sustainable.

By combining all of these efforts, data centers can become more cost efficient and environmentally friendly. Nevertheless, implementing such changes is not without its challenges. As with any substantial transformation there is pushback, but the overall benefits make it worthwhile.

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4 Challenges

As with any industry, a large-scale change faces many challenges. Furthermore, working towards net zero emissions does not directly increase a company's bottom line. Of course this means that companies will work to maximize profit, sometimes at the expense of others. However, that doesn't necessarily mean we are doomed.

4.1 Cost

Obviously there is a large start up cost to going green. Purchasing new equipment and funding research are just a few examples. Additionally, having to take a data center offline to convert it or possibly even breaking it down to move it would result in massive costs as services won't be available to users. This pressures a company to just keep what they have working, and not to mess up a good thing.

4.2 Technology

While no one can say for sure, it is highly unlikely that the creators of the ENIAC data center put much thought into the environmental impact of their machine. For almost its entire infancy, data centers did not grow around net zero, they grew around profit. Thus, as the technology advanced, growth in net zero did not. Now we are playing catch up, and new technology is being researched and developed in ways that reduce power, heat, and other side effects. However this R&D does come at a steep price.

4.3 Future Trends

The future of data centers is promising as they continue to embrace sustainability trends. Big Tech industry leaders are increasingly going green, with giants such as Amazon setting the goal to power their operations with entirely renewable energy by 2025. We are also witnessing a shift towards new storage and cooling solutions, including the adoption of hydrogen fuel cells to reduce environmental impact[Saur20]. Additionally, the integration of AI and machine learning in workload management systems allows for enhanced energy forecasting models, ensuring data centers meet both their service and environmental goals[Koot21].

Why the path is daunting, there is light at the end of the tunnel. With large companies paving the way and the research being done, the path to net zero has never been more promising.

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5 Summary

This paper explores growth towards net zero data centers, emphasizing their critical role in mitigating environmental impact. The need for bigger and better has brought groundbreaking technologies, renewable energy, and sustainability practices. Unfortunately, there are key factors that prevent the rapid industry wide change that is needed. Nevertheless, data centers are continually improving and making positive strides while following the lead of Big Tech and the government.

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6 List of Acronyms

- GHG - Green House Gas
- LCA - Life Cycle Assessment
- PUE - Power Usage Effectiveness
- WUE - Water Usage Effectiveness

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