Energy Efficient Networking Starts with Big Data Centers

Introduction

The single most pressing issue that humanity is facing today is mass consumerism and the consequences of said mass consumerism. The human species is strip mining every resource it can get its hands on and then dumping the byproducts of manufacturing and using those resources into the very air that it breathes and the water that it drinks. Humanity is destroying the very habitat that we need to survive.

An environmentalist will be quick to point out the fallacy of such actions. There can be no justification for the potential extinction of the human race. Society must find a way to stop the destruction of our ecosphere.

This inevitably leads to finger pointing. A very large and very wealthy corporation can be an easy target. These corporations are seen as faceless, and often evil entities by the general public. They are seen as the drivers of this consumerism, and therefore most responsible for the results of this consumerism.

The amount of energy a company consumes is often used as a benchmark for assessing its role in the destruction of the environment. Energy usage is linked to more emissions of greenhouse gases, and greenhouse gases are linked to higher temperatures and the resulting chaos that will come from said higher temperatures. Therefore, when the public sees new innovations, such as the hyperscale data centers that are becoming commonplace nowadays, using power at previously unheard-of rates, they are quick to point the finger and label them as part of the problem.

However, what the general public often forgets to factor into the equation is its own personal responsibility in the need for these large data centers. It is not that corporations are demanding that data centers be built to push their agenda, it is that corporations are building data centers to satiate the public demand. The public has grown to expect that the benefits of the cloud will always be available to them. Today's internet user expects the six 5MB 4K photos of their dinner to instantly appear across a dozen social media platforms and be backed up to their cloud storage. When eight billion people all do that at one it adds up to a lot of data.

"In 2025, the world will generate 181 zettabytes of data, an increase of 23.13% year over year" (DemandSage, 2025).

That's 181 trillion gigabytes**.** 70% of that is user generated. (DemandSage, 2025) Any IT professional can tell you that amount of data is going to require a lot of spinning disks. It's going to require backup. It's going to require chips that process and retrieve that data. It's going to require machines to cool those chips so they can run with five nines uptime. All of that is going to require a lot of energy.

"Data centers currently consume around 2% of global electricity, and that figure could rise to 10% by 2030" (Honeywell, 2025)

That's around 570TWh a year, nearly double that of the entire United Kingdom. That's a tough pill for any environmentalist to swallow. The world's energy resources are dwindling. How could such a cost ever be justified?

Let's explore the alternatives.

The first option, and by far the first choice of any true environmentalist, is to shut it down. Society uses the internet only when absolutely necessary. Public use is almost entirely curtailed. The internet and data storage are tightly regulated. Society accepts their own personal responsibility for their part in the destruction of the environment. The economy crashes. Hard. The resulting chaos and job loss combined with lost productivity leads to widespread poverty, mass death, and a complete rewriting of societal norms. Eventually, society begins to rebuild and collectively accept that we need to take a more responsible approach to our relationship with the environment. Society survives, but at a cost.

The second option would revert to the fragmented infrastructure of the early internet and store all of the data that we use in small, decentralized data centers. Each company would store their own data on their own physical servers. They would be maintained and monitored by whomever the local IT person is. These small data centers would take the early 2000's "any means necessary" approach to networking. Servers would be operating at almost a full power load yet would be operating at 18% server capacity due to preparation for unexpected usage spikes. Servers would be cooled by a local HVAC unit or the small plastic fans they came with. They would be stored in buildings that were designed to hold offices and desks or in closets that were designed to hold dirty mops. These server rooms and IT closets would be powered by the local power grid, and they would use whatever power source the local grid uses. Could be wind. Could be coal.

"Smaller, less efficient data centers and server closets often lack the scale and incentives to implement energy-saving technologies." (Shehabi et al., 2024)

The third option is to use the big data centers that have become the target of environmental groups and social media keyboard warriors the world over. These centers would be operated by trillion-dollar companies who have a gigantic financial incentive to make them as energy efficient as possible. These companies would have the means to buy all of the most cutting-edge and energy efficient information technology equipment available. These companies would have the means to not only implement the newest cooling technologies, but to invent new ones. All of their equipment would be monitored by the latest AI technology which would continuously scan equipment and adjust cooling as necessary. These data centers could host thousands of different companies all at one location. They could operate at much higher capacities while still accounting for usage spikes. The companies that run these data centers could build their own renewable energy power plants and could use them to power not only the data centers themselves, but also heat the surrounding communities.

“Hyperscale data centers have the potential to operate carbon-negative when paired with DAC and powered by renewables.” (Honeywell, 2025)

Let’s evaluate our three options.

The first option is the best for the long-term survival of the human race. If the people who will be born after the year 2100 had a vote, this is undoubtedly the option that they would choose. Unfortunately for them, and the future of the human race, they aren’t here, and the people who do get a say in the matter have panic attacks when they can’t log on to their favorite social media site for an hour. The fact is our entire economy depends on the world’s digital infrastructure, expecting society to abandon this foundation is not only impractical, but it would also be economically catastrophic. This option is simply off the table.

That leaves us with the last two options. We can either go back to the ways of the early 2000’s where the internet was a patchwork of servers in office building basements and broom closets, or we can move forward and take advantage of every possible technological advantage we have.

The choice is clear. When it comes to tech, the answer is almost always to go with the latest and greatest whenever you can. This case is no exception. The large sprawling data centers that the public have labeled as so destructive towards the environment are actually much less destructive than what companies were doing before the cloud came along. Data set after data set supports this statement. As long as people insist on using big data, the best way to go about it is to take advantage of the newest and most energy efficient technology available to us. Data centers are not a sign of a corporate AI takeover; they are the best possible solution to our internet addiction.

Related Work

- **Impact of Data Centers on Climate Change: A Review of Energy Efficient Strategies**

This is a great white paper to start with when it comes to data centers. It offers a lot of hard data on the power consumption levels of data centers. The first thing that was very interesting about this article was that it said,

“A report from the International Energy Agency (2023) posited that data centers globally consumed about 1-1.5% of the world's electricity.” (Ewim et al., 2023, p. 4)

What’s fascinating about this is that just two years later another report said that we were already up to around 2%. This is notable because there are experts who believe that we could be around 10% by 2030.

This paper goes on to talk about all of the contributors to the environmental footprint of data centers. There are direct emissions which come directly from the infrastructure the data centers use. Servers are the most power hungry machines in the building. The always on processors are constantly sifting through data and serving it up to the needy client. There are also cooling systems. One worry about these is that the refrigerant in them could leak and cause an environmental disaster. There are also backup generators. While companies like Microsoft are moving towards using Hydrogen generators, most places still use diesel.

Indirect emissions also play a huge role in the carbon footprint caused by data centers. There are emissions that are caused by the physical construction of the infrastructure, the materials used in the construction, and the materials used to manufacture the equipment used. There is also one of the most important factors to consider when considering the environmental impact of a data center, its energy source. While some companies have taken steps to construct their own self-sustaining green energy centers, most still use the local power grid. Where that power comes from is an important consideration. If you are using the local grid in West Virginia, you are probably using coal. If you are using the grid in Washington state or Vermont, you are probably using much cleaner hydroelectric power. Companies that are committed to green energy must consider this when choosing where to build.

This paper also does a great job in comparing the data center greenhouse gas (GHG) emissions to that of other industries. When you account for all of the indirect emissions,

“Data centers account for 2.5% to 3.7% of global GHG emissions, which exceeds the GHG emissions from the aviation industry recorded at 2.4%” (Ewim et al., 2023, p. 5)

This graph from the paper does a nice job of representing the data:

(Ewim et al., 2023, p. 5)

Furthermore, with emissions rising, data centers could surpass even the giants when it comes to greenhouse gas emissions,

“data centers, in their current state, might have a lower emission profile, but the trajectory of growth in digital services suggests that without intervention, data centers could rival, or even surpass, the automotive industry's emissions in the coming decades.” (Ewim et al., 2023, p. 5)

This paper does an excellent job of ending on a high note though. It speaks of how important governance is in providing a framework for data centers to operate in. As discussed, where you build can have a significant impact on your emissions levels. Fortunately, places like Finland and Norway have enacted laws to help companies build data centers that are as green as possible. Two great examples are Google's Zero Carbon Data Centre in Finland and The Green Mountain Data Centre in Norway.

• **Honeywell: Design for More Efficient Data Centers**

The Honeywell paper is a great resource. It serves as a user’s manual for data centers and provides the reader with a lot of valuable information. This paper also serves as an introduction to PUE, or power usage effectiveness. This is an excellent metric for evaluating the efficiency of power usage and helps put the overall power consumption of data centers into perspective. It is important to note that while PUE is an excellent benchmark, it should not be taken as a hard metric. DAC, or direct air capture, can raise a company’s PUE, but by implementing DAC, companies can actually lower their overall carbon footprint.

“The energy efficiency of data centers is usually expressed in terms of the power usage efficiency (PUE), which is the ratio of the total electricity consumed by the data center to the electricity consumed for IT operations. A lower PUE is more efficient in use of electricity for DC operations; however, PUE does not account for any use of waste heat, so fixation on PUE can disincentivize energy reuse and lead to designs that have worse overall environmental performance.” (Honeywell, 2025, p. 5)

DAC is a process that pulls carbon out of the air and actually makes it usable again. Waste heat from data centers, supplemented by heat pumps, can power DAC plants. When this is combined with a renewable energy source such as wind this process can actually help to reverse climate change and provide carbon that can be used for building materials.

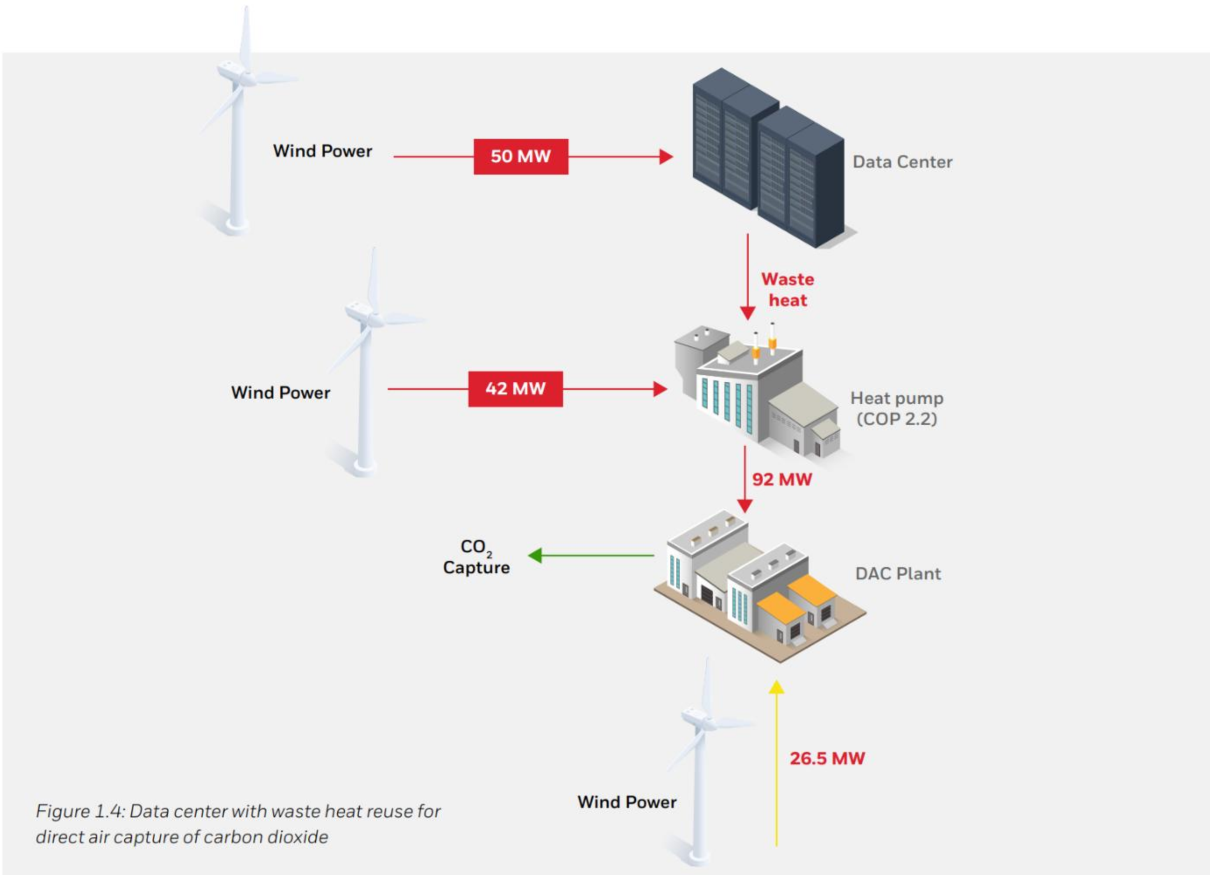


Figure 1.4: Data center with waste heat reuse for direct air capture of carbon dioxide

“Our lifecycle analysis calculations suggest that if such a facility is powered with low C-intensity electricity it can be carbon negative.” (Honeywell, 2025, p. 9)

It should be noted that this process is expensive and much of the technology is still in its infancy. Most of the data center waste heat reusage today is focused on heating homes that are nearby data centers. This is why for most purposes PUE will remain an excellent way to judge a facilities overall energy usage efficiency.

This paper also points out the two main strategies for managing the energy use of data centers. The first strategy is to integrate thermal management early in the lifecycle and to consider the entire lifecycle when deciding on thermal management techniques. The second strategy is to make use of all available automation and analytics techniques.

The first strategy stresses planning for waste heat reuse when designing a facility's cooling system and using new techniques such as two-phase liquid cooling and thermal energy storage. Thermal energy storage is a technique that stores cooling energy produced at non-peak times and uses it at peak times.

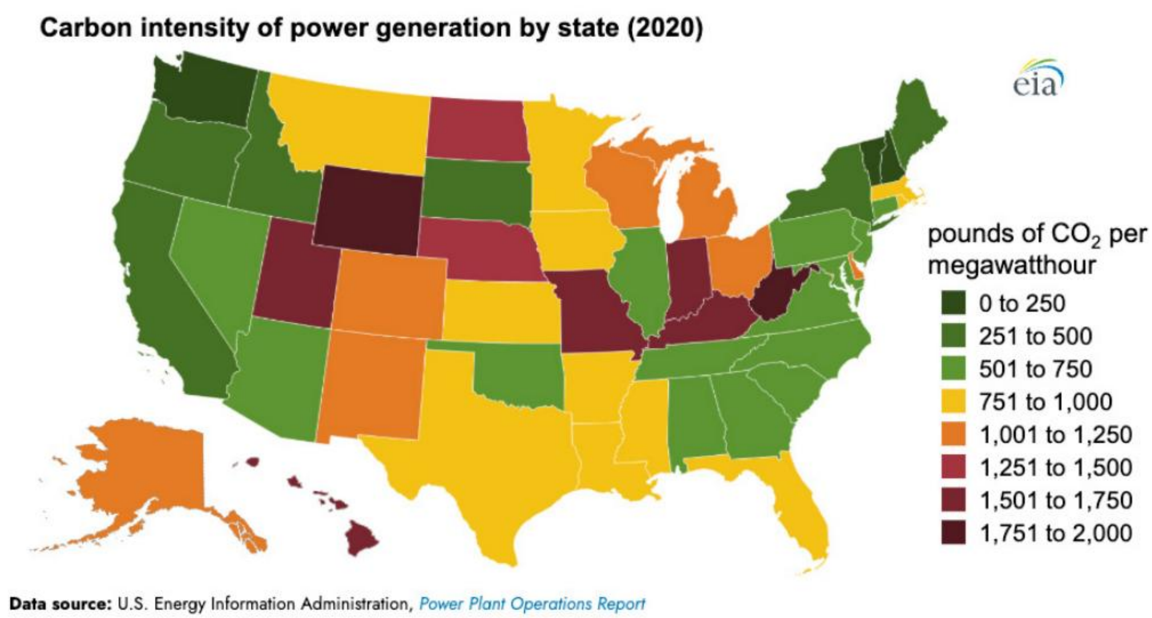
"By spreading thermal energy production over 24 hours, this solution can reduce chiller demand charges by 30 to 70%" (Honeywell, 2025, p. 13)

The second strategy is, essentially, to use computers to tell us how to properly use computers. This is a strategy that is already paying huge dividends. The gigantic scale that modern data centers present allow them to be used very efficiently by new computer algorithms.

"between 2010 and 2018 U.S. data center computing workloads increased nearly 550%, while energy use only increased 6%" (Honeywell, 2025, p. 4)

This is only getting better as well. Honeywell recommends that companies continuously upgrade their information technology hardware and software so that they take advantage of the most modern techniques and use them to save energy and costs. Analytical tools that take advantage of today's AI algorithms can offer early warnings in regard to failed equipment and can automatically monitor and shift cooling to where it's needed.

Honeywell also stresses the importance of the place where engineers choose to build their data centers.



“Site selection is the single most important factor for data center environmental footprint, as it creates the boundary conditions that govern the viability of many sustainable design options” (Honeywell, 2025, p. 6)

This seems like an obvious one. Not only can the energy source you use be a crucial factor in the cost and environmental impact, but the latitude you choose can have huge benefits as well. A data center built in a cold location (Canada, Norway, Finland) can use “free cooling” year-round. Free cooling is exactly as it sounds, using the cold outside air to cool your equipment at no cost. Considering cooling typically accounts for 30-40% of a data center’s total power usage, this can drastically cut costs and PUE.

• **<u>Improving Energy Efficiency for Server Rooms and Closets</u>**

This article is key to understanding the benefits that modern data centers present. As we mentioned before, the option of simply shutting off all of these servers is not viable one, therefore we must find the most efficient way possible to store and process our data. In the pre-cloud internet days, most companies ran their own private servers. They were stored on site and were often run very inefficiently.

“Typical servers in server rooms and closets run at very low utilization levels (5-15% on average), while drawing 60-90% of their peak power.” (Bramfitt, Mark, et al., 2012, p. 2)

This is important to note. A server that represents the needs of an entire company cannot just contain the hardware necessary to account for its typical usage, it has to account for usage spikes. If you have a server that only receives ten requests per hour for 23 hours a day but receives ten million requests per hour one hour a day, it must have the equipment necessary to be able to handle fifty million requests an hour at all times. It has to account for its highest normal usage, plus spikes. The rest of the day it just sits and sucks power. In a large data center those usage spikes can be accounted for and distributed among the servers that serve tens of thousands of other clients. Furthermore, they can be cooled much more efficiently because they are placed in buildings that are specifically designed to hold servers and cool them.

“Server rooms are not designed with energy efficiency in mind. They are often cooled by the building’s HVAC system, which is not optimized for the heat load of IT equipment.” (Data Foundry, 2023)

This leads to a PUE that is significantly higher than those found in data centers. When implemented on the scale necessary for modern data needs, this can have gigantic ramifications. Consider this chart:

Space	PUE	Server Power Consumption	Total Power Consumption of Space	kWh per year	Annual CO_2 emissions (metric tons)
Server Room	2	5 kW	10 kW	87,600	61.6
Converted Closet	2.5	5 kW	12.5 kW	109,500	77.9
Data Center	1.5	5 kW	7.5 kW	65,700	46.2

*Calculations based on 10 servers per room with an average consumption of 500W each.

(Data Foundry, 2023)

Hyperscale data centers are getting more efficient by the day. A PUE of 1.0 means perfect efficiency, all energy usage goes directly to computing. At many hyperscale data facilities a PUE 1.2 and below is the norm.

“We report a comprehensive trailing twelve-month (TTM) PUE of 1.09 across all our large-scale data centers” (Google)

Microsoft reports an average global PUE at its hyperscale data centers to be around 1.16. A PUE difference such as this on a global scale is massive. If the modern internet is to continue operating as the people expect it to, the choice is clear that large data centers are the most efficient way to use the energy needed to power it.

• **<u>Research Advances on AI-Powered Thermal Management for Data Centers</u>**

One of the key issues in dealing with data centers is that there are so many different aspects of it to manage. The idea that a human, or a team of humans, could efficiently manage all the needs of a hyperscale data center is preposterous. This is where our new friend AI comes into play.

Considering that around 40% of a data center’s power usage goes to cooling it stands to reason that if a company were to be able to monitor and adjust cooling in real time, based upon the needs of the machines involved, quite a bit of money and energy could be saved. AI can help these companies save energy.

“AI can significantly enhance thermal management due to its accuracy in predicting situations and finding optimal or near-optimal solutions.” (Liu et al., 2022, p. 304)

Furthermore, with the large-scale implementation of virtual machines the problem of efficient management only gets worse. One server can host many virtual machines, each of which has its own schedule. The large-scale data centers of today can house hundreds of thousands of servers. Each of those servers can have tens, or hundreds, of virtual machines. It would be impossible for a human to optimize all of this. Fortunately, AI thrives in such a disjointed environment.

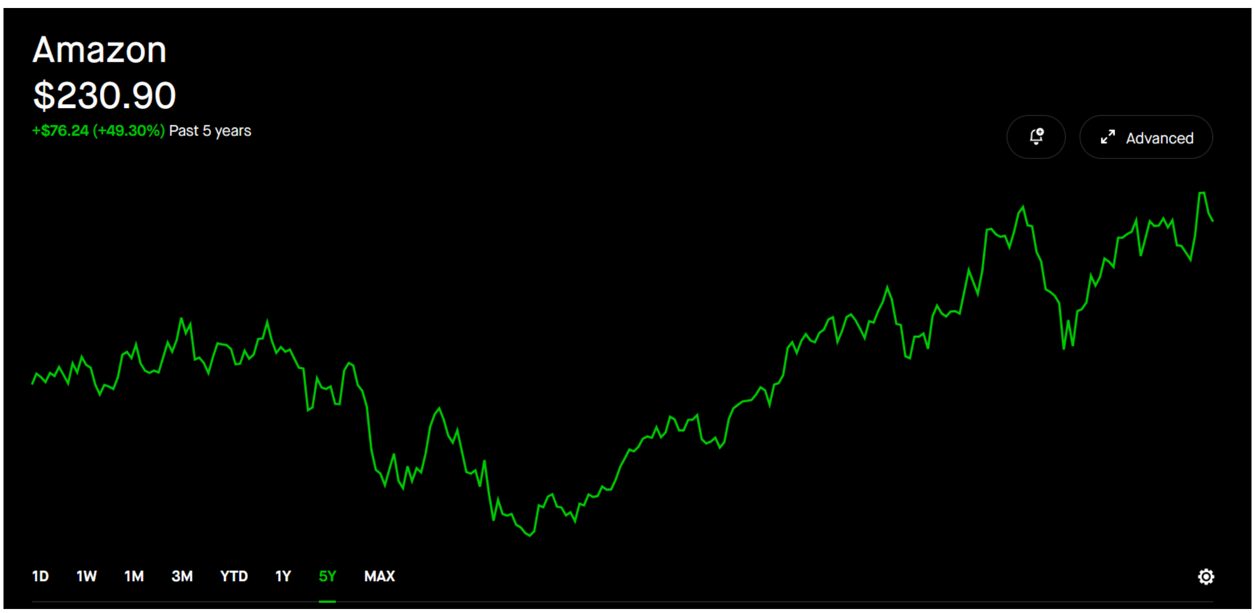
“AI-powered thermal optimization leads to improved process scheduling and consolidation of VMs and eliminates the hotspot from happening.” (Liu et al., 2022, p. 303)

In other words, we must build even more data centers to store the massive datasets that machine learning algorithms require to optimize cooling in the hyperscale facilities that exist so modern internet users can share six 4K photos of their cake across a dozen social media platforms.

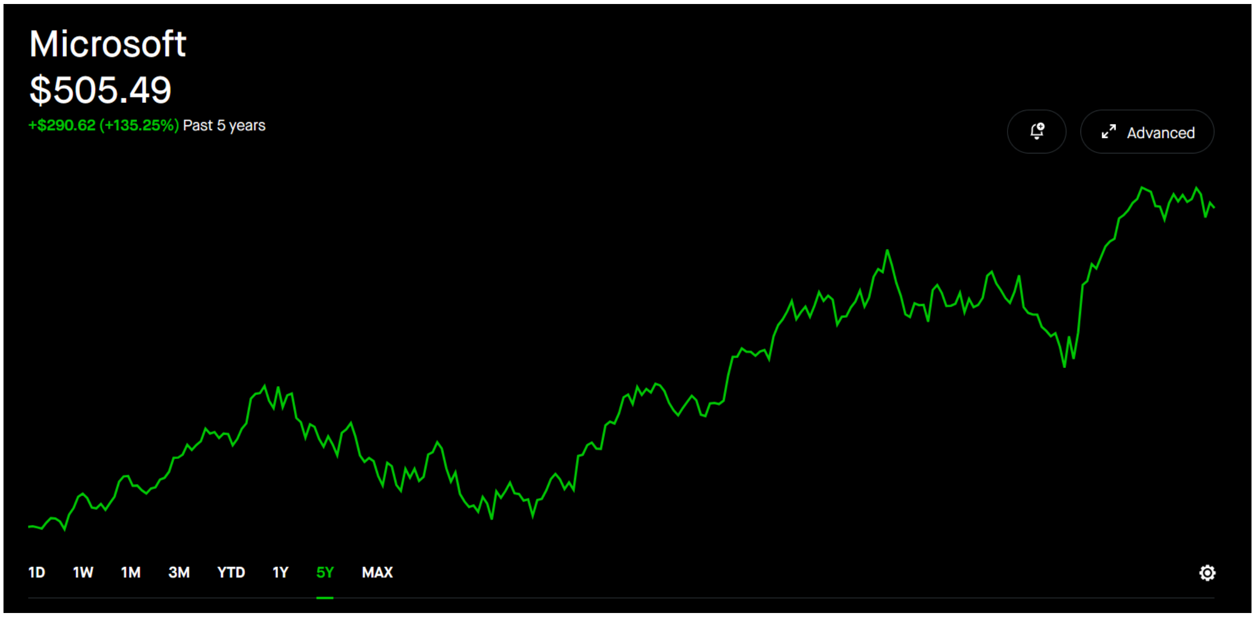
Discussion

The more that one reads about the massive data centers that are sprouting up all over the globe, and compares them to the alternatives, the more one can’t help but fall in love with them. That’s exactly what smart investors have been doing as of late. In the last five years the stock prices of the big three cloud computing companies have risen dramatically.

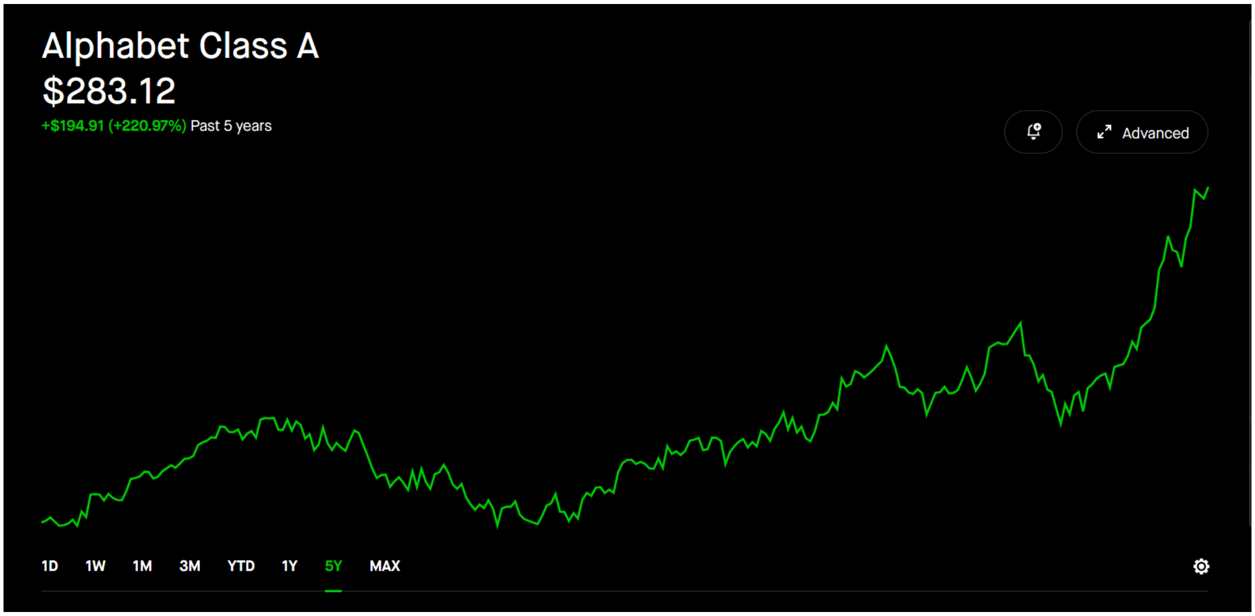
Amazon is up “only” 49%. (88% the last three years)



Microsoft is up 135%.



Google is up 220%.



It's true that there is talk of an AI bubble, but those who are aware of the facts know that there is only growth ahead. Datasets are not getting smaller. People are not sharing less information. All of these companies are seeing massive profits at a large scale and have the infrastructure and client base necessary to justify their high stock prices. This is not the dot com bubble of the early 2000's. People are not pouring money into html code and a catchy domain name. These are proven companies whose products are already used by billions worldwide. It's always a good idea to invest in such companies.

"[The hyperscale data center] market will grow from $3.48bn in 2024 to $9.49bn by 2030." (Energi People, 2025)

With such growth come jobs, good jobs that anyone would be proud to have.

“The 2025 Data Centre Jobs Snapshot reveals a sector in the middle of its biggest building boom yet.” (Energi People, 2025)

Although there will be fewer jobs available due to the proliferation of AI management, there is still lots of work to be done by human hands. There are few things that are more tantalizing to a fresh tech school graduate than the prospect of working in a large data center surrounded by the newest technological advancements. This is yet another reason to build more data centers.

The most effective way to spur companies to build data centers, and create the jobs that accompany them, is to offer financial incentives for doing so. Fortunately, many states are starting to recognize the benefits that data centers can have.

“At least 41 states are offering tax incentives to encourage data center development.” (Axios, 2025)

This is an excellent start. Tax incentives like this spur growth and create economic opportunities. Unfortunately, the right states are not offering the best financial incentives. Texas, for example, offers great financial incentives. Those incentives, combined with cheap power costs, make it an attractive location for new data centers. However, Texas relies heavily on fossil fuels. Data centers built there will be emitting greenhouse gases at a much higher rate than if it was built in a state like Vermont, which almost exclusively uses renewable energy sources. If governments were to offer higher tax incentives for building self-sustainable data centers, perhaps companies would be more incentivized to build their data centers using renewable energy. Unfortunately, while the hyperscale leaders are committed to building such centers, many of the smaller companies have no such plans.

This brings us to the limitations we must consider when excitedly discussing this topic; all of this is about money. It’s nice that some of the leaders in the industry are considering the environmental costs when building these centers, however, many of these technologies are years away from being implemented. Climate change and resource exhaustion are already in a perilous state. These data centers are poised to be using 10% of the world’s total energy output by the end of the decade. Can we really bank on companies that exist only for profit to hold true to their promises?

Furthermore, is this really necessary? The major assumption here is that people are driving the proliferation of data centers through their own conscious actions. Is that really the case? Do people genuinely have the free will to say no to the internet in this day and age? One could reasonably argue that the environment in which modern humans reside requires that we be connected to the internet. It is necessary for jobs, school, and even social interaction. Do we really have a say in the destruction of our environment? Could we find a better way?

Conclusion

There is one thing that we know for certain right now; the internet isn't going anywhere anytime soon. It has become indispensable to modern life, and it gets bigger by the day. The alternatives have been explored. The undeniable truth is that the best possible scenario is one in which hyperscale data centers are given the task of handling the data and processing necessary for the modern internet to function as intended. Yes, the energy costs of these centers are enormous, but the alternatives are even worse.

In the world of 2025, it has become common to adopt a victim stance and loudly condemn the perceived wrongs of major corporations. Yet we must acknowledge that it is our own lifestyles and expectations that drive the need for these corporations to act as they do. Criticizing data centers without understanding the facts accomplishes nothing. Furthermore, posting on social media about the evils of data centers is no different than preaching about how eating meat is wrong while eating a veal sandwich.

Society must accept that data centers are here to stay, and, if implemented properly, they can be a force for good in shaping a sustainable digital future.

References

Ewim, Daniel Raphael Ejike, et al. *"Impact of Data Centers on Climate Change: A Review of Energy Efficient Strategies." The Journal of Engineering and Exact Sciences*, vol. 9, no. 6, 2023, pp. 16397–01e, https://doi.org/10.18540/jcecvl9iss6pp16397-01e.

Honeywell. "*Design for More Efficient Data Centers: How Automation and Analytics Throughout a Data Center Lifecycle Can Help Reduce Energy Use and Environmental Impact*." Honeywell, 2025, https://www.honeywell.com/content/dam/honeywellbt/en/documents/downloads/hon-corp-design-for-more-efficient-data-centers-whitepaper.pdf

Ezeigweneme, Chinedu Alex, et al. "Telecommunications Energy Efficiency: Optimizing Network Infrastructure for Sustainability." *Computer Science & IT Research Journal*, vol. 5, no. 1, 2024, http://www.fepbl.com/index.php/csitrj/article/view/700.

Clifford, Catherine. "Data Centers Are Eating the Economy—and We're Not Even Using Them." *Fortune*, 11 Aug. 2025, https://fortune.com/2025/08/11/data-centers-are-eating-the-economy-and-were-not-even-using-them/.

Bramfitt, Mark, et al. *Improving Energy Efficiency for Server Rooms and Closets*. Environmental Energy Technologies Division, Berkeley Lab, Oct. 2012, http://hightech.lbl.gov/documents/data_centers/fact-sheet-ee-server-rooms.pdf.

"Server Room vs. Data Center Energy Efficiency." *Data Foundry*, https://www.datafoundry.com/server-room-vs-data-center-energy-efficiency/.

Shehabi, Arman, et al. *United States Data Center Energy Usage Report 2024*. Lawrence Berkeley National Laboratory, Dec. 2024, https://eta-publications.lbl.gov/sites/default/files/2024-12/lbnl-2024-united-states-data-center-energy-usage-report_1.pdf.

Liu, Hui, et al. "Research Advances on AI-Powered Thermal Management for Data Centers." *Tsinghua Science and Technology*, vol. 27, no. 2, Apr. 2022, pp. 303–314. https://doi.org/10.26599/TST.2021.9010019.

"Tax Incentives for Building and Operating Data Centers." *AbitOs Accountants + Advisors*, 10 July 2025, https://abitos.com/tax-incentives-data-centers-2025/.

"2025 Data Centre Jobs Snapshot – Skills, Hiring Trends & Market Outlook." *Energi People*, 11 Aug. 2025, https://energipeople.com/2025-data-centre-jobs-skills-hiring-trends/. Accessed 15 Nov. 2025.

DemandSage. "Big Data Statistics 2025: How Much Data Is Created Every Day?" *DemandSage*, 2025, https://www.demandsage.com/big-data-statistics/.

Google. *Data Center Efficiency*. Google, https://datacenters.google/efficiency/.

Microsoft. Data Center Sustainability: Efficiency. Microsoft, https://datacenters.microsoft.com/sustainability/efficiency/.