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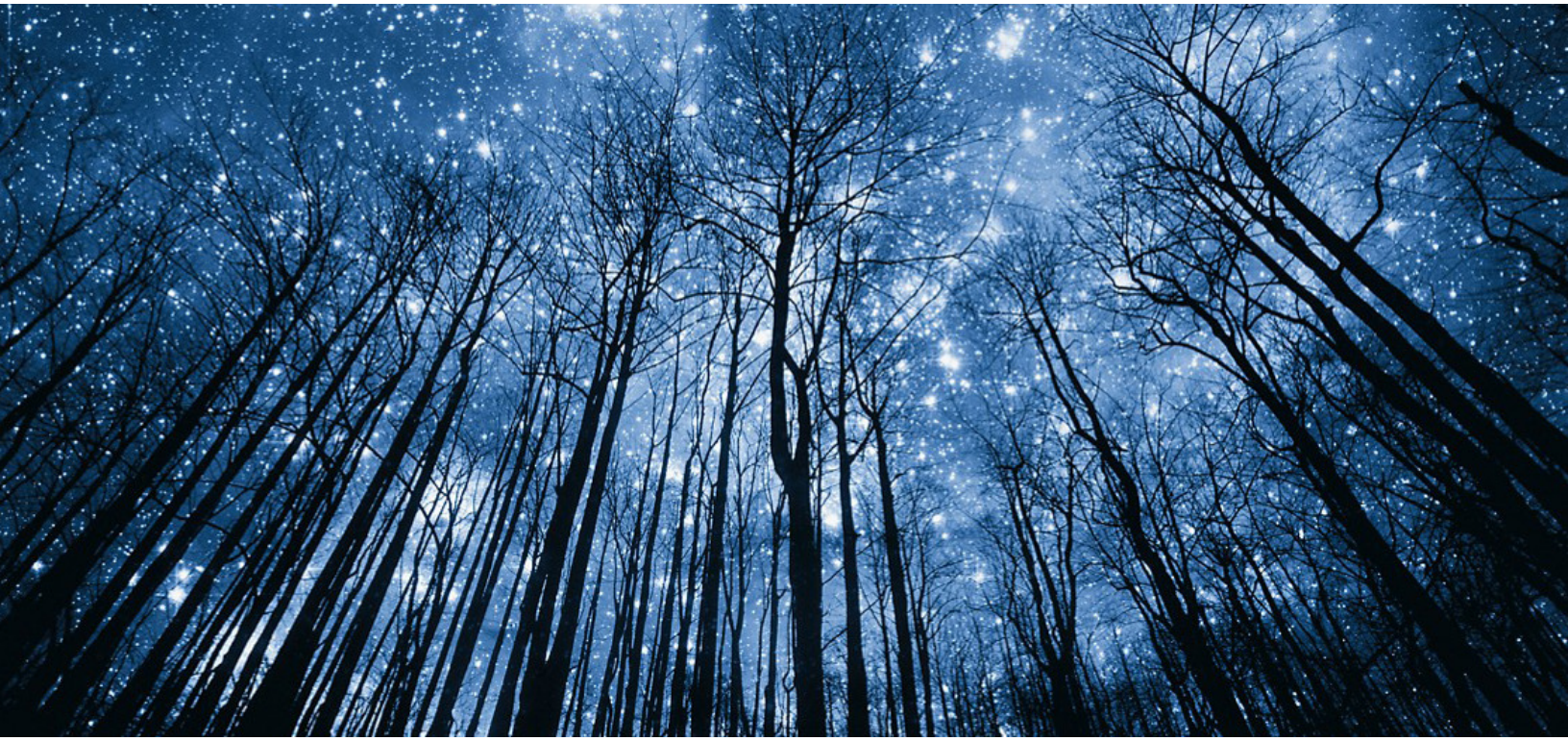
DECARBONIZATION: TOWARDS SUSTAINABLE DATA CENTERS



Kartik Sumrani
Associate Sales Engineer Analyst
Dell Technologies

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Abstract

Data is increasing exponentially, and so is the need for data centers. Ten years ago, data centers were virtually nonexistent. Now, they account for about 2% of all greenhouse gas emissions and consume 3% of the world's electricity. Experts predict that the amount of energy used by the world's data centers, which store billions of gigabytes of data, will triple in the next ten years. This will put a huge strain on energy resources and will likely prove to be a hefty blow to contain global warming.

An effective data center decarbonization plan must involve IT management, data center/facilities management, and sustainability management. Leaders of sustainability and data center solutions are working together to make sure that new solutions cover the entire carbon footprint and address all aspects. This paper attempts to explore various solutions and strategies which major companies are employing to tackle the issue.

This paper intends to impart knowledge in the following areas:

1. The data center market in the coming decade.
2. Decarbonization and sustainability
3. Current strategies and solutions deployed

Introduction

The data center remains of the most crucial pieces of business infrastructure, even as more and more businesses try to become major players in today's data-driven economy. Many organizations were already in the throes of digital transformation before the COVID-19 pandemic accelerated the pace of business across the globe. If you believed that the pace of the pre-pandemic world was already fast, the luxury of time now seems to have disappeared completely. Businesses that once mapped their digital strategy in one- to three-year phases are now scaling their initiatives in days or weeks. This quickening is evident across sectors and geographies. Consider how banks have rapidly migrated their physical channels online, how healthcare providers have moved into telehealth, and retailers into contactless shopping and delivery. According to a survey conducted by IDC, in 2017 only 29% of all offerings were either fully or partially digital, and by mid-2020 this number jumped to 55%. This shows that more than half of the customers in the world now interact with businesses through a digital channel. It is evident that the number of data centers worldwide will continue to rise as connected technologies become more mainstream and Internet penetration rates continue to rise. While many aspects of our social, commercial, and economic lives are supported by these data centers, we cannot ignore the fact that they are some of the world's largest power consumers given the impending climate crisis.

The environmental impact of data centers is significant and is growing rapidly. They consume 2% of the world's energy, roughly the same as the aviation industry, according to various estimates. Additionally, this could account for 42% of all IT related power consumption by 2025. If we go with the current statistics, only half of the world's population is now connected to the Internet. Despite this, IDC noted that there are now over 8 million data centers worldwide, up from 500,000 in 2012. Data centers continue to use twice as much energy every four years, making this the fastest-growing carbon footprint sector. This has become a major cause for concern, not only because of the high costs involved, but also because of the carbon emissions that will follow.

The latest climate change analysis shows that there is a dire need to act now and find ways to reduce the carbon footprint and adopt sustainable solutions. This global emergency goes beyond national borders and necessitates international cooperation and coordinated solutions at all levels.

At the United Nations Climate Change Conference (COP21) in Paris, world leaders agreed to significantly reduce global greenhouse gas emissions to limit this century's temperature rise to 2 degrees Celsius and to continue efforts to limit it even further to 1.5 degrees Celsius. In 2019, the United Nations Environment Program (UNEP) estimated that to move closer to the 1.5°C temperature target set by the Paris Agreement, global carbon emissions must be reduced by 7.6% annually for the next

decade. The regulatory actions and increasing environmental concerns are forcing a paradigm shift in the way IT solutions are designed and managed throughout their lifecycles. The positive upside is the demand for a carbon-neutral infrastructure and sustainable developments have been gaining momentum and awareness within the data center industry. Businesses have been working to tackle the challenge that lies ahead.

Overview of Data Centers

What is a Data Center?

Data Centers are the soul of the modern-day storage system. Without a secure and robust data center, the whole business structure would crumble. They enable digitalization and allow companies to deal with gigantic amounts of data on an everyday basis. To define, a data center is a physical facility that businesses use to operate, manage, and store their critical applications and data. There is a lot going on in a data center — servers, storage systems, routers, switches, firewalls — all of which come together to accomplish the main goal of housing the infrastructure. Its design is based on computing and storage resources that make it possible to deliver applications.

Following are the three components of data centers:

1. **Facilities:** The physical facility which houses all the infrastructure. It typically has a floor that is raised, and power and network cables are held in place by ducts underneath.
2. **IT Infrastructure:** Includes cabinets, compute systems, storage, and connectivity elements.
3. **Supporting Infrastructure:** Includes heating, ventilation, air conditioning (HVAC), fire, and power supply systems. Biometrics, and badge readers. Video surveillance systems are also included in this category of security systems.

Data centers are designed and built to fulfill the key characteristics as shown in the figure below.

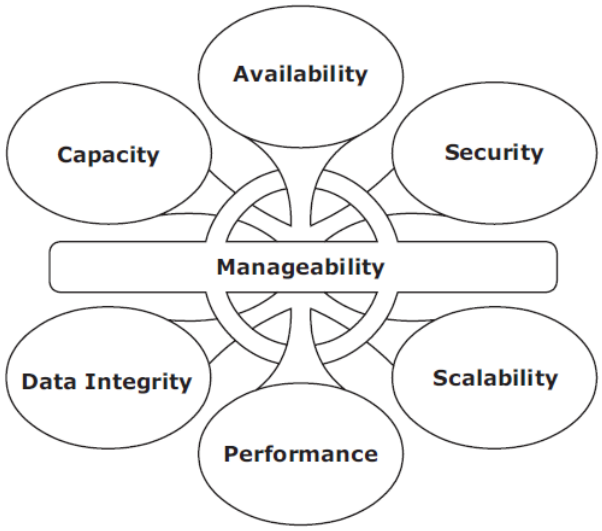

Figure 2.1: Data Center Characteristics

Data Center Architecture and Design

Data center architecture is an architectural design that creates connections between servers and switches. It specifies the placement of the server, storage networking, racks, and other data center resources and addresses their interconnection.

The design of a modern data center has moved away from an on-premises infrastructure and toward one that combines on-premises hardware with cloud environments in which networks, applications, or workloads are virtualized across multiple private and public clouds. Because all components are no longer co-located and can only be accessed via the Internet, the design of data centers has been completely redesigned. There are typically four different types of data center architecture: mesh point of delivery (PoD), super spine mesh, three-tier or multi-tier model, and mesh work [FS Community].

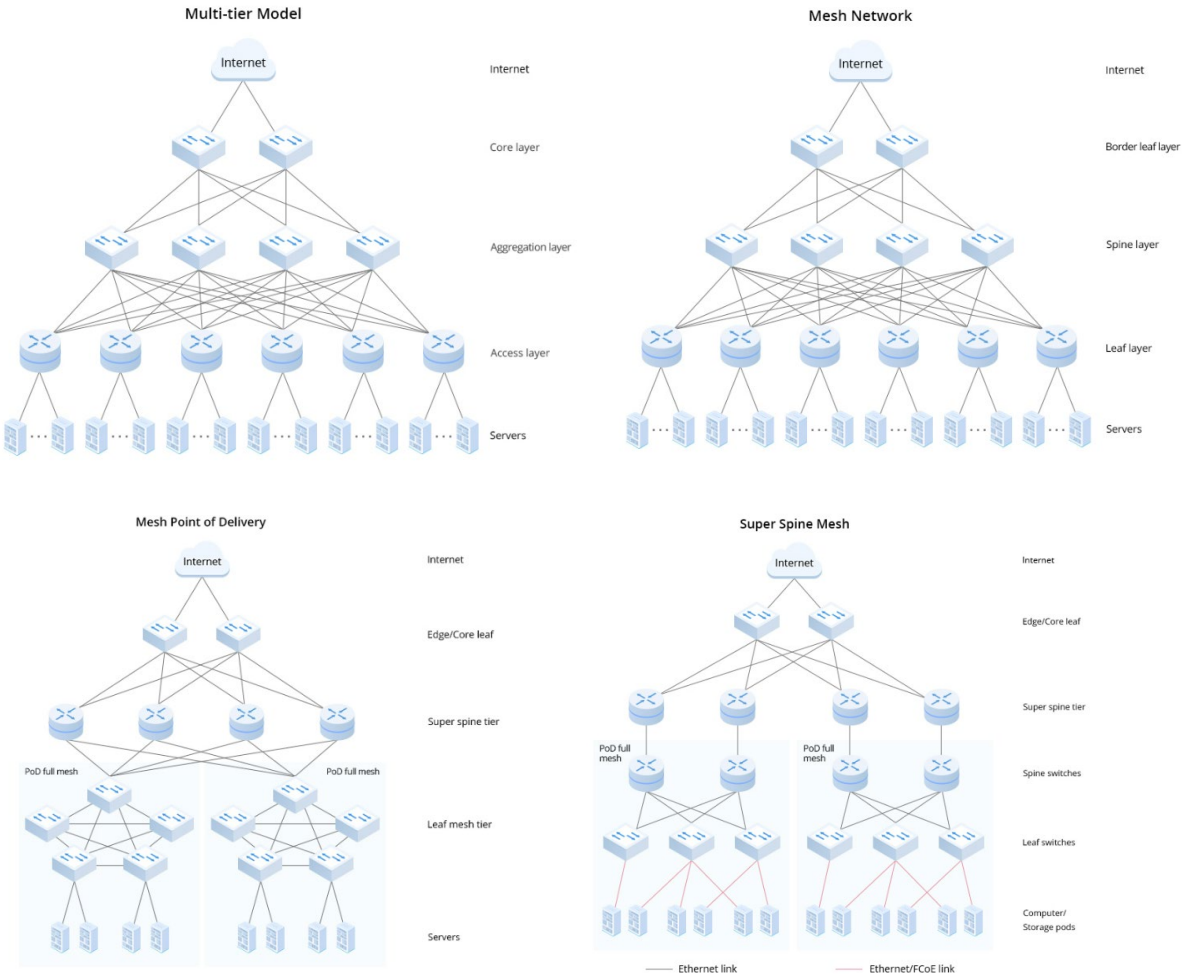

Figure 2.2: Data Center Architecture

The entire design process for a data center focuses on making the most of IT resources to increase efficiency, boost sales, and to reduce environmental impact. By focusing on aspects such as performance, space, modularity, and sustainability, solution architects can achieve maximum efficiency out of the data center. Therefore, data center planning is crucial and one of the most important steps to achieve sustainability.

Following are the design considerations that companies currently employ when building a data center:

1. **Logical Design:** Includes modeling and designing the data center's architectural layout and entire infrastructure. This acts as a blueprint for the data center's design and other considerations.

2. **Location of Data Center (Site):** Includes proximity to power grids, telecommunications infrastructure, networking services, transportation lines, and emergency services. Companies also consider environmental and regulatory aspects when designing and building a data center. These aspects will facilitate smooth data center operation.

3. **Data Center Environment:** A data center's physical environment is tightly controlled. The data center's temperature and humidity are controlled by ventilation and air conditioning (HVAC).

4. **Security Considerations:** Biometrics, badge readers, and video surveillance systems are included in this category of security systems. Data centers are equipped with state-of-the-art security controls to make sure that they are up and running.

5. **Energy Efficiency:** The data center energy efficiency metric is defined by a formula PUE = Total Facility Power/Total Equipment Power. The best efficiency of a data center would be represented by an ideal PUE value of 1. A PUE value of 1 indicates that all the power entering the data center is being used to power IT equipment. Any value above 1 indicates that data center overhead is required to support IT load.

The pre-installation, installation, turnover, and testing of various elements of an IT infrastructure within a data center is the focus of data center implementation. One must maintain vigilance over the quality and safety of the data center throughout the implementation process; Everything, from raised floors to effective cooling, must be carried out according to plan.

Exploring Sustainability through Design and Metrics

Decarbonization

The need for decarbonization has never been more pressing, and this is due to the fact that greenhouse gas emissions have been rising steadily. Let's begin by considering the fundamental definition of decarbonization in order to comprehend the increasing importance of the subject. ‘Decarbonization’ refers to reducing ‘carbon intensity’ and lowering the level of greenhouse gas emissions produced by a multitude of sources.

Now that we know what decarbonization is, one must wonder if there are any definite methods or frameworks through which we can decarbonize? Although the specific plan depends on each business, I would like to present a general framework which any business can undertake to move toward a sustainable future.

1. **Know your Business and Current Potential:** Know where you are currently in the journey to decarbonize and then prepare metrics to understand baseline emissions. This enables you to set workable goals and make decisions more quickly. You can curate and analyze data with the help of data solutions such as software and AI (Artificial Intelligence) to implement a well-thought-out decarbonization strategy. You will have an easier time using the data and drafting your strategy to decarbonize.
2. **Set Annual Targets and Checks:** Announce your goals after analyzing and understanding the data. One of our studies found that businesses are more likely to set ambitious goals, achieve those goals more quickly, and achieve success when goals are announced.
3. **Deploy Strategies and Act on them:** Once you have goals and numbers, the next step is to take action. This could mean reducing travel, reducing unnecessary shipping, improving logistics efficiency, or updating your facilities with green technologies, depending on your industry. With the development of technology, most industries would require a unique combination of infrastructure upgrades, data management, digital solutions, and other elements to reduce their carbon footprint.
4. **Assess Periodically:** The world of decarbonization is always changing and if you want your decarbonization strategy to be successful, it is essential to keep up with the most recent innovations and technologies.

These four strategies provide a very basic framework for most businesses, but overcoming decarbonization challenges requires collective efforts and strategic commitment. Issues with basic reporting due to data format and quality, data timeliness, and disparate data sources make it difficult to gather numbers and understand the real challenge. When reports are available, they frequently lack details and obscure opportunities for reducing carbon emissions. Management, product design, supply chains, industrial processes, distribution networks, circularity, and technological innovation all will play a crucial role in determining successful trade-offs.

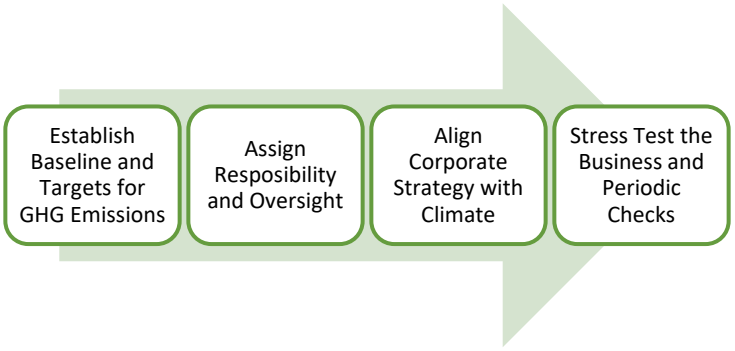

Figure 3.1: Decarbonization Framework

Decoding Decarbonization and Business

Sustainability is not embraced solely by companies for the benefit of society. Climate change is driving up business costs, and with the predicted exponential growth of data over the next ten years, making data processing and storage more sustainable at every step is now a crucial consideration. Decarbonizing a business means continually attempting to reduce carbon emissions from all activities. It may necessitate downsizing if you live in a large office complex. If your executives frequently fly out on business trips, video conferences may be the preferred way to do business. Switching to cleaner energy or investing in carbon capture and storage may be necessary if your business relies on energy from fossil fuel power plants. Decarbonizing your business comes with some short-term sacrifices, but there are also long-term benefits involved.

1. Green data centers help reduce total cost of ownership (TCO) and increase return on investment (ROI) by increasing productivity and efficiency.
2. Numerous industries discuss going green, and a business can promote a positive brand image for itself, and its data center services by converting energy-intensive data centers into green ones.
3. Businesses are subjected to significant regulatory pressure to go green. Technology and pollution standards, market instruments (green taxes, trade permits, ecosystem services), information disclosure, and voluntary policies make up most of these policies. In their annual reports, some of the best green data center operators formally document initiatives under environmental, sustainability, and governance (ESG).
4. Governments are largely driving the effort for businesses to reach net zero. This indicates that your company has an advantage over competitors due to incentives to go green, such as grant funding for decarbonization efforts and favorable press coverage for green good news stories.
5. Increased resilience, lower costs, higher efficiency, and a brighter future for all stakeholders.

Sustainable Data Center Characteristics and Metrics

According to Google Cloud research, 90% of IT leaders say sustainability is a priority for their departments and 67% have already set targets to reduce their impact on the environment. The need for green data centers has been recognized. To comprehend the concept of sustainability from a resource-based perspective, data centers can be divided into multiple areas:

1. **Energy Usage:** The new data center design must focus on decreasing energy usage and increasing energy efficiency. Increasing the energy efficiency per

computation lowers two factors - Cooling need and the primary need of the electricity by the IT equipment. Optimizations at various points, including Power Distribution Unit (PDU) and Uninterruptible Power Supply (UPS), can be implemented to increase energy efficiency. Upgrading to an energy efficient data center infrastructure will help in decreasing the energy usage and carbon footprint.

2. **Heat Management:** A massive amount of heat is produced by current state-of-the-art data centers. Ventilation and central air conditioning units cool the entire room where the racks are also stored in air-cooled systems. The cooler the air needs to be, the higher the energy and water consumption. The reason for this extensive cooling of the hardware is that the components are frequently not certified for higher temperatures and are said to perform best in those conditions.

3. **Waste Creation:** By buying components for these data centers, it also produces increased waste, causing further harm to the environment. The acquisition and maintenance of the data center's components is a challenge given that the hardware becomes outdated and needs to be refreshed. Refreshing the system means that the outdated hardware becomes e-waste if not reused. Recycling e-waste, electrical and electronic equipment will help in the journey towards sustainability.

4. **Data Growth:** A rising demand for data computation follows the trend of increasing data creation. The need for computation is linked to that data. As a result, more data necessitates more computation, which in turn necessitates more resource consumption.

5. **Facility:** The infrastructure of a data center must be housed in a real building. The construction of new facilities goes hand in hand with the rising demand for computation power. Similarly, new facilities would necessitate the use of numerous resources and oil. New approaches to designing buildings that are more sustainable are currently being developed by the construction industry.

This breakdown of the data center's impact areas should make the issues more understandable and simplify holistic topics that affect all resources. The reason for this is that the resources cannot be seen on their own. They are extremely interconnected. For instance, an increase in computation productivity results in less hardware being required, less heat, and less energy consumed. Additionally, it saves facilities space and reduces waste.

The extended perpetual lifecycle of data center components and new metrics for environmental and network resource consumption must be used by providers of data centers for their systems. Based on the resource-based parameters, the new metrics will help assess the data center sustainability and provide numbers to the leaders.

1. **Power Usage Effectiveness (PUE):** A data center's energy efficiency can be assessed using the power usage effectiveness (PUE) metric. The power used to operate IT equipment in a data center is divided by the total amount of power entering the facility to calculate PUE. PUE is expressed as a ratio, and as the quotient approaches 1.0, overall efficiency rises. It is a widely used standard for data centers to measure their power efficiency.

2. **Water Usage Effectiveness (WUE):** The Green Grid developed the sustainability metric known as Water Usage Effectiveness (WUE) in 2011 with the intention of attempting to quantify the amount of water utilized by datacenters to cool their IT assets. A data center manager divides the annual site water use in liters by the energy use of IT equipment in kilowatt hours (Kwh) to calculate simple WUE.

3. **Land Usage Effectiveness (LUE):** The LUE is measured as the amount of land used per kW for IT capacity.

4. **Network Usage Effectiveness (NUE):** The average rate at which network connectivity is used in comparison to the quantity purchased. This metric will help assess the areas where technical advancement/interference is needed to reduce environmental impact.

The above metrics help us comprehend the advantages and disadvantages of material choices, manufacturing byproducts, repairability, part reuse, and landfill impact, through which we can improve the long-term sustainability of data centers. So, what are forward-thinking businesses doing to improve the sustainability of their data centers? They are moving towards sustainable and green data centers.

Traditional data centers currently do not keep track of the waste produced during construction and operation. A sustainable approach is to accurately track all waste throughout its lifecycle and move towards re-use, recycling, and re-manufacturing efforts. We envision the next generation data centers to operate entirely on renewable energy and have a net zero carbon footprint, emissions, and waste. This should be accomplished while achieving optimal resource (power, water, land, and network) utilization efficiency, such as a PUE close to 1.000 and a WUE close to 0.000.

Sustainable data centers make use of renewable energy sources, reuse materials to extend their useful lives, remanufacture byproducts, and lessen the amount of waste that ends up in landfills. Additionally, the data center components can be designed to have their own sustainable lifecycles by making use of a modular system. As a result, the data center's long-term path is significantly smoother. Simply making each module sustainable is all that is required to make a site's structure sustainable.

Figure 3.2: Sustainable Data Centers

Other than physical infrastructure, companies must also focus on processing data more efficiently at every stage of the life cycle to improve the sustainability of their data processes. Optimizing networks and data transmission, realizing the value of small data, eliminating storage waste, and driving efficiency in workload management are a few goals. Data compression, deduplication, and thin provisioning are a few of the options available to businesses wishing to implement lean principles and reduce data storage waste.

Snapshots offer the ability to restore data if it is accidentally overwritten before being transferred to a secondary backup and assist with frequent updates. The effective use of virtual machines can be utilized to supplement these methods. However, the financial and environmental costs of data storage tend to mount up without ongoing evaluation. We must make better use of storage to take advantage of the technology that is available to us.

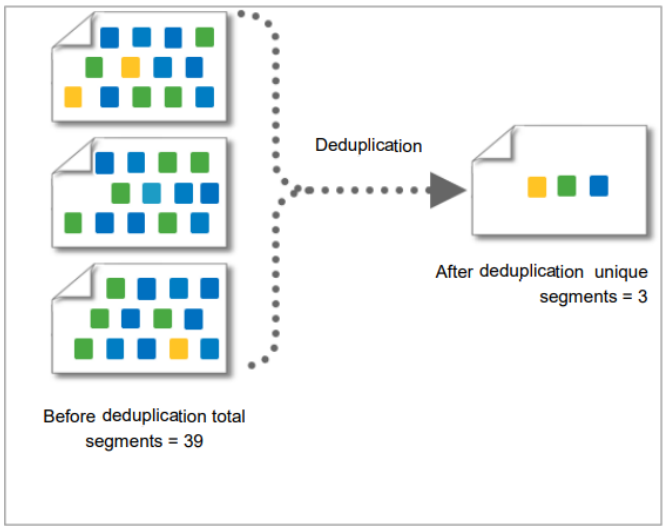

Figure 3.3: Data Deduplication as one of the ways to improve storage efficiency

While businesses are clamoring for AI and big data, we must not forget that even modest improvements to AI models can result in significant energy consumption. Encoding, quantization, and pruning are all methods that can be used to make AI models environmentally friendly. Additionally, businesses must be aware of the numerous advantages of smaller data sets.

For instance, they frequently provide granular insights that are better suited to individual decision-making. Maintaining and managing smaller data sets results in lower costs and a smaller environmental footprint. Sustainability is not embraced solely for the benefit of society. Given the exponential data growth, making data processing and storage more sustainable at every step is now a crucial consideration.

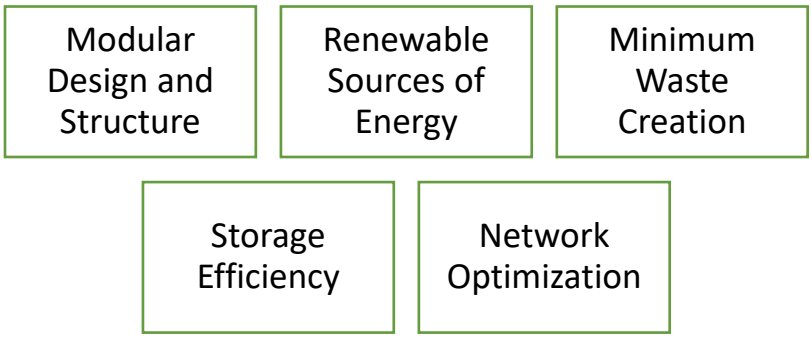

Figure 3.4: Sustainable Data Center Characteristics

Current Decarbonization Strategies in the Market

A book-length discussion is required to develop an IT strategy for businesses to navigate sustainability. To start, workloads in applications must be modernized to cut down on infrastructure footprint and operating system overhead. Up to fifty percent of server capacity can be saved through app modernization alone in some instances. Businesses are also able to begin removing data silos and, when this occurs, they can extract and improve organization-wide data insights and automate day-to-day tasks, both of which can result in cost savings and agility for the company. Companies have already started acting on decarbonization and sustainability goals. The following section lists out a few strategies that are currently deployed in the market.

Case Study 1: Corporate way to Decarbonization

Industries are moving toward decarbonization and announcing their targets and plans to deal with the environmental impact. On similar grounds, a technology giant has listed their plans to decarbonize data centers and how they plan to achieve net zero. To start with, they have taken a systematic approach to understanding and reducing the carbon footprint:

1. Assessment and Plan: Build a strategic and appropriate roadmap by understanding carbon reduction goals, today's realities, and data challenges. This step involves assessing the current state of infrastructure and definitive targets along with a strategic roadmap to align corporate strategy with climate change.

2. Carbon Insights Dashboard: Drive GHG reduction and operational tasks with dashboards, key performance metrics, and aggregated data. Data solutions such as software and AI can be used to curate and analyze data to implement thoughtful decarbonization strategies.

3. Asset Assessment: Leverage deeper asset-centric assessments and analytics to identify opportunities for carbon reduction and operational efficiency improvements.

4. Asset Optimization: Implement asset replacement and improvement strategies to reduce your carbon footprint and see potential impacts using advanced modeling and recommendations.

Their comprehensive suite of data center carbon reduction solutions addresses the many challenges associated with the data center and its related hardware, software, and operational components. A combined portfolio of green data center solutions can help advance sustainability goals, no matter where one stands in their data center decarbonization journey. They have given various solutions to aid companies in their bid to reduce the environmental impact.

The Carbon Insights Platform provides visibility and insight into data center carbon sources to enable data center sustainability managers to efficiently analyze, plan strategy, and audit results. It increases transparency for all stakeholders and helps businesses understand carbon footprint based on consumed IT infrastructure (memory, servers, network), data center energy consumption, and data center overhead. By equipping data center managers with this knowledge, they can develop strategies to reduce their carbon impact. Their data center optimization solutions provide ways to maximize output and reduce carbon footprint.

These include:

1. **MV Microgrid:** The medium voltage microgrid uses transformers and solid-state converters to greatly reduce energy loss effectively and pave the way for the replacement of diesel generators.

2. **Battery Energy Storage System:** Centered around lithium-ion (Li-Ion) batteries, BESSs are emission free. Moreover, "they have a better cost-effectiveness than a corresponding diesel genset configuration."

3. **HVAC Artificial Intelligence:** Virtual sub-measurement, monitoring, and management platform to optimize HVAC related technologies and reduce carbon footprint. It reduces gas/electricity by 5-20%.

4. **Virtual Storage Array with Application Modernization**: State-of-the-art storage hardware designed for performance, scalability, resilience, efficiency, and carbon footprint optimization.

All these techniques will help decarbonize data centers and reduce the environmental impact.

Case Study 2: Dell Technologies Advancing Sustainability

Climate change action keeps us all occupied. This technology offers a significant opportunity to reduce emissions and mitigate global warming on a large scale. That's why Dell Technologies is committed to innovating and improving our products and solutions to help our customers and partners meet their emissions goals. When it comes to product design, they consider the entire life cycle – reducing emissions at every stage for less waste, greater energy efficiency and a lower carbon footprint of the product. These efforts include delivering sustainable products. reducing product carbon footprint, partnering for a green data center, leading in eco-labels, and as-a-service opportunity

Goals and targets are essential for decarbonization and sustainability plans. Dell Technologies has also announced their targets to achieve net zero GHG emissions by 2050. These goals enable today's focus on sustainability to meet rising energy costs – from power and cooling to IT system efficiency. These goals are not just limited to net zero emissions.

1. By 2030, for each product a customer buys from Dell Technologies, they will reuse or recycle an equivalent product.
2. By 2030, 100% of packaging will be made from recycled or renewable materials and more than half of their products will be made from recycled or renewable materials.
3. By 2030, they will generate 75% of our electricity from renewable sources at all Dell Technologies facilities and 100% by 2040.

Figure 4.1: Dell Technologies Targets and Goals

These goals give customers the confidence in knowing that Dell is making a long-term investment to meet the required sustainability needs. Dell's leadership has consistently demonstrated this with their commitments, actions, and sound business practices to deliver innovative products and solutions that help customers achieve their sustainability goals. There are three ways for Dell's modern storage portfolio to enhance sustainability: Energy efficiency, heat and cooling and infrastructure consolidation.

Figure 4.2: Dell Technologies Sustainability Plan

Energy Efficiency: Reducing the energy intensity of products and technologies and making them more efficient with each new generation is the primary goal.

Technical advancements have helped Dell reduce the power intensity of HCI products by up to 83% since 2013 and have increased the power efficiency on PowerEdge servers by 29% over the previous generation. Ten years ago, it took six servers to do what is possible on one server today. In addition, PowerMax delivers 80% power savings per TB and up to 7x capacity increase per array in half the rack space compared to the previous generation, all while maintaining 99.9999% availability. And

Dell PowerStore 3.0 delivers up to 60% more IOPS per watt. Dell innovates all their state-of-the-art storage solutions, including flash storage, data replication, and data compression, allowing customers to consolidate hardware and save energy, while reducing their footprint their physics.

Thermal and Cooling: Dell storage is designed for adaptive cooling to reduce power consumption. The fan speeds up when the ambient temperature increases or CPU usage increases, to maintain the optimal temperature without using more power than necessary. Most Dell server and storage products will have at least one titanium power supply by 2023. Titanium power supplies (PSUs), as assessed by the 80 PLUS program, use less electricity to power server and emit less heat, resulting in significant energy savings. about cooling.

Infrastructure Consolidation: With Dell innovations like data reduction and high-density flash drives, one can avoid overprovisioning by doing more for less: less raw storage, less power and cooler and less hardware. In fact, the entire PowerStore portfolio offers higher data density than an equivalent line of all-flash arrays from a competing supplier. Better data density helps reduce your carbon footprint by optimizing and maximizing effective terabytes per rack unit.

At Dell Technologies, the vision is to be the most essential technology company in the data age. They do this by redefining IT with a modern, software-defined, open architecture designed for the digital future, giving our customers simplicity, flexibility, capability, and control over their technology, leading to better business outcomes in a SaaS, distributed, and multi-cloud world.

Conclusion

Climate change is accelerating, and the next decade will be the one that defines global efforts to dramatically reduce greenhouse gas emissions, limit global warming, and mitigate the effects of climate change. It is important to continue to emphasize the urgency of action to contribute and achieve targets put forward by the Paris Agreement, and although the 2050 deadline is deliberately set to match the race to zero, it is imperative to set goals as ambitiously as possible,

Data center decarbonization is essential due to its growing demand and the carbon footprint it leaves behind. To improve decarbonization in the short term, sourcing renewable energy (ideally from local and complementary sources) will impact the data center on a much larger scale, against any performance measure. Looking toward the future, data center operators must continue to strive to achieve more efficient operations.

This paper concludes by presenting a general framework and approach to reduce the negative environmental impact of data centers, followed by case studies outlining what corporations are doing currently to achieve net zero and stay on the path of sustainability. It is time to take a holistic approach to decarbonization and sustainability that goes beyond our own business and to enable industry-wide carbon removal solutions and harness our power to drive climate action with science-based goals.

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