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# 3.2 Making Data Centers Green

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## Abstract

Rapid expansion of digitisation and need for environmental sustainability brings to the forefront the immediate need for green data storage systems. Green data centers aim to minimize the environmental impact of data center operations by reducing energy consumption, optimizing resource utilization, and adopting sustainable practices.

This article brings out the issues and challenges faced by data centers and comes up with innovative solutions. The key areas of concern highlighted are inefficient cooling systems, reliance on non-renewable energy sources, and poor utilization of server resources. Article then tries to explore various solutions that include infrastructure design, server virtualisation, scalable designs and dynamic workload management. These measures further enhance the utilization ratio from current 5-10% to 50% thus reducing the carbon footprint vis-a-vis the data stored. Article also highlights Server virtualisation and consolidation as the most viable solution for greening data centers.

Considering the fact that digitisation will exponentially increase in future with the expansion of AI, Machine Learning and Big Data Analysis, sustainability becomes a crucial point of improvement in the sector. The article therefore explores this area to reduce its power consumption, resource wastage and carbon footprint.

## Keywords

Green Data Centers, Environmental Sustainability, Energy Consumption, Carbon Footprint, Server Virtualisation, Renewable Energy, Cooling Systems, Water Conservation.

## Introduction

Humanity generates 65 zettabytes data in a year-- enough to max out the storage capacity of about 40 million iPhones -- every *day*. Much of it gets stored “in the cloud,” meaning it’s saved in sprawling, frigid data centers. Unfortunately, these data centers are contributing to the destruction of the environment[i]. Data Centers

consume as much as 3-13% of the world's total annual electricity consumption -- and are responsible for emitting more than 200 million metric tons of carbon dioxide, on par with the annual emissions from all commercial air travel in the entire United States. The carbon footprint due to data storage reaches nearly 1.73 g $CO_2$/GB in the minimum scenario while this figure has risen to approximately 1.98 g $CO_2$/GB and 4.11 g $CO_2$/GB during both the median and the maximum scenarios, respectively. Data centers are on track to account for 14% of all global emissions by 2040. That's equivalent to what the entire United States currently emits[ii]. -

Current research suggests that networks and data centers consume more than computers. Communication networks, including mobile, fixed broadband and telephone networks, consumed 1.7% of total global electricity usage a decade back while data centers consumed about 1.4%[iii]. There is a marked movement towards cloud-based usage of data storage as well as low power consuming small devices like laptops and mobile phones rather than desktops. There is a strong trend to push electricity consumption onto the network and data center infrastructure where energy costs are less transparent to consumers[iv]. It is estimated that powering a LED TV for watching a movie takes a similar amount of energy (120 Wh) as consumed in streaming it over the Internet[v]. In fact, the largest share of energy consumption is made by network and data centers as compared to the lifetime of tablets and smartphones consuming at least 90% of the total energy use including manufacture and charging[vi].

## What are Data Centers

Data centers are indispensable for any IT organization, providing capacities for centralized storage, management, backups, dissemination and networking of data in which the lighting, electrical, mechanical and computing systems are designed for maximum sustainability and minimum energy usage. Data centers are found in all major sectors of the economy including financial sector, educational, industrial and ICT. Data Centers are used to help business processes, automation, information dissemination and communications. Rapid increase in the size and number of data centers due to ever increasing demand has boosted the demand for both physical infrastructure and IT equipment as well as energy consumption[vii]. Data center IT equipment consists of many individual devices like storage devices, servers, chillers, generators, cooling towers and many more. But servers are the key power guzzling component. Their size and numbers increase in proportion to the data usage. This will further cause massive increase in energy consumption, and unintended consequences like over-sizing of heating and cooling equipment.

This resultant increase in production of Greenhouse gases which are hazardous for ecological health is more costly than the cost that will be undertaken in efforts to make data centers green. Data Centers also consume disproportionate amounts of water ranging from 3-5 million of gallons of water per day which is equivalent to the water demand of a city of 30,000-50,000 people. Solutions also need to be drawn for firstly reducing the water intake and secondly reuse and recycle of waste water[viii].

## Overview of the Field of Data

Data can be categorized into various types based on different criteria such as structure, source, and purpose. Some common types are:

1. *Structured Data:* Data with a well-defined schema and organized format, typically stored in relational databases or tabular formats such as CSV (Comma-Separated Values) files. Examples include data stored in databases, spreadsheets, and structured text files.

2. *Unstructured Data:* Data that does not have a predefined schema or organized format. It can include text documents, images, videos, audio files, social media posts, and sensors. They are often stored in file systems or NoSQL databases and require advanced techniques such as natural language processing (NLP) and machine learning for analysis.

3. *Semi-Structured Data:* A hybrid form of data that does not conform to a rigid schema but contains some structural elements, such as tags, labels, or attributes. Examples include XML (eXtensible Markup Language) files, JSON (JavaScript Object Notation) documents, and log files[ix].

Further, critical data, redundant data, and dark data are terms used to describe different aspects of data management and utilization:

1. Information that is necessary for an organization's operation and success is referred to as critical data. It contains information that has an immediate bearing on customer satisfaction, regulatory compliance, business processes and decision-making. Few examples are Customer data, financial transactions, product inventories, personnel data and intellectual property related data. Maintaining business continuity, risk management and competitive advantage all depend heavily on the availability, integrity and security of vital data.

2. Duplicate or unnecessary data that is present in an organization's data storage systems are referred to as redundant data. Numerous issues arise with this kind of data including poorer system performance, higher storage costs and problems with data quality. Also, by introducing errors and inconsistencies it further makes data management and analysis tasks more difficult. Enhancing data quality, streamlining processes and lowering storage costs can all be achieved by locating and removing redundant data through data deduplication, data cleansing and data consolidation procedures.

3. Data that an organization gathers processes and stores but does not actively use to produce insights or inform decisions is referred to as dark data. They could be dispersed throughout various systems and repositories and frequently exist in unstructured formats like text documents, emails, log files and social media posts. Dark data has enormous potential but organizations have yet to fully utilize it. Fully utilizing it would result in improvements in operational effectiveness, risk reduction and innovation. Organizations can uncover the value of dark data by using advanced analytics machine learning and data discovery techniques to find patterns, trends and correlations that can guide strategic initiatives and enhance business results[x].

To sum up, dark data is unrealized potential concealed within an organization's data assets, redundant data is needless duplication within data systems and critical data is crucial for organizational operations and success. In the data-driven world of today maximizing value, lowering risks and generating competitive advantage depend on efficiently managing and utilizing these various forms of data.

Further, certain storage techniques are more environmentally friendly than others when looking at sustainability:

1. **SSDs or Solid-State Drives:** SSDs are generally regarded as more environmentally friendly than HDDs because of their longer lifespan and lower power consumption. They are also less likely to break mechanically and waste energy like spinning disks do as they do not have any moving parts.

2. **Tape Storage:** Requiring very little power when not in use, tape storage is among the most energy-efficient storage solutions. Moreover, because of its long lifespan, storage media do not need to be thrown away or replaced as often.

3. **Cloud Data Storage:** It may be a more sustainable option than on-premises storage thanks to its ability to optimize infrastructure utilization and pool resources Cloud providers can reduce their environmental impact by utilizing renewable energy sources and energy-efficient data centers[xi].

The environmental harm caused by our addiction to data storage has long been acknowledged by numerous companies and environmentalists. Certain companies have made a commitment to power their data centers with renewable energy sources such as Meta. It is necessary to keep centers cool so others have worked to replace inefficient air conditioning systems and upgrade outdated servers to newer more energy-efficient models. Of course, those actions are beneficial but only marginally.

## Solutions Proposed

It takes a combination of operational enhancements, technological advancements and strategic planning to turn data centers that are already in place into green and sustainable buildings. To accomplish this, we need to follow these steps:

1. **Assessment of Energy Efficiency:** To find areas where energy consumption can be optimized carrying out a thorough assessment of energy efficiency helps. This entails evaluating the lighting server usage power distribution and cooling systems[xii].

2. Increase server utilization rates and decrease the number of physical servers by implementing server virtualization and consolidation techniques. As a result, resource efficiency is increased and energy consumption is reduced[xiii].

3. **Improved Cooling Systems:** Adding energy-saving features like variable speed fans, hot/cold aisle containment and precision cooling systems reduces energy consumption drastically. Energy consumption and cooling efficiency can both be increased by putting airflow management strategies into practice[xiv].

4. **Renewable Energy Integration:** To reduce the amount of energy used for data center operations, data centers need to include renewable energy sources like solar wind or hydro power. This may entail putting in place systems for producing renewable energy on-site or buying renewable energy credits from outside vendors[xv].

5. **Energy Management Software:** Energy management software to track and improve energy use in the present moment, automating energy-saving measures and offering insights into patterns of energy consumption can optimize energy usage.

6. **Eco-Friendly Hardware:** Replacing outdated hardware with newer more energy-efficient models that adhere to industry guidelines and earn certifications. Server peripherals, networking hardware and storage devices fall under this category.

7. **Waste Heat Recovery:** Using Combined Heat and Power (CHP) systems to produce additional electricity or to collect and repurpose heat produced by data center equipment for heating[xvi].

8. **Water Conservation:** Cutting down on water usage in data center operations use water-efficient cooling technologies like closed-loop cooling systems or evaporative cooling. Install water recycling systems as well if at all possible[xvii].

9. **Building Design:** Integrating energy-efficient lighting insulation and building automation systems into existing infrastructure through the use of green building design and trying to earn a LEED (Leadership in Energy and Environmental Design) certificate[xviii].

10. **EmployeeAwareness and Training:** Encouraging a culture of environmental responsibility, training data center employees on energy-saving methods and sustainable practices, motivating staff members to embrace energy-efficient practices and actively engaging in environmental projects.

## Establishing New Data Centers in a Sustainable Manner

Globally establishing new green and sustainable data centers necessitates meticulous planning and the application of creative solutions. The following actions can be performed:

1. Renewable Energy Integration: Giving careful consideration to location identification where renewable energy resources like hydro wind or solar power are in abundance. To power data center operations installing on-site renewable energy generation systems such as wind turbines or solar photovoltaic arrays should be undertaken.

2. The implementation of energy-efficient design principles such as hot aisle/ cold aisle containment can enhance airflow and minimize cooling energy consumption. To reduce the energy needed for temperature regulation cutting-edge cooling techniques like liquid cooling or direct fresh air cooling should be used.

3. Modular and Scalable Architecture: Data centers should be designed with a scalable and modular architecture that enables resource optimization and incremental expansion in response to demand. This reduces resource waste and permits the effective use of infrastructure[xix].

4. High-Density Computing: To decrease physical footprint and increase compute power per square foot, high-density computing hardware such as FPGA (Field-Programmable Gate Array) accelerators or blade servers should be used. This lessens its impact on the environment and improves energy efficiency[xx].

5. Using Power Distribution Units (PDUs) with integrated energy monitoring and control features is one way to implement smart power management systems. To maximize power usage effectiveness (PUE) and minimize energy waste cutting-edge power management software should be deployed.

6. Water Conservation: To reduce the amount of water used in data center operations water-efficient cooling technologies like closed-loop cooling systems or evaporative cooling need to be used. Systems for recycling and reusing water should be installed to reduce impact on the environment.

7. Green Building Certification: For sustainable building design and construction practices green building certification such as BREEAM (Building Research Establishment Environmental Assessment Method) or LEED (Leadership in Energy and Environmental Design) need to be pursued. This indicates a dedication to sustainability and environmental responsibility.

8. Make a commitment to carbon neutrality by investing in carbon offset projects or buying renewable energy credits (RECs) to offset the carbon emissions caused by running data centers and balancing carbon emissions with comparable reductions or offsets aimed to achieve carbon neutrality.

9. Eco-Friendly Materials: When building data center infrastructure use environmentally friendly materials and construction techniques such as low-impact building materials recycled content and sustainable sourcing

techniques. Throughout the course of the project reduce waste production and advance the concepts of the circular economy.

10. Employee Education and Awareness: Data center employees need to be instructed and educated on energy-saving techniques, environmental stewardship and sustainable practices. By encouraging a sustainable culture within the company and giving staff members the freedom to participate in eco-friendly projects, one can create a global network of environmentally conscious employees that prioritize environmental responsibility and reduce ecological footprint by implementing these measures into the planning, design and operation of new data centers.

## Way Ahead

The first step should be taking charge of data storage policies and making sure no data is being kept longer than necessary[xxi]. The removal of unstructured data from data centers results in reduced expenses, better regulatory compliance, reduced emissions and environmental protection. Data centers need to start enhancing their data management procedures and employ the right tools to determine which data is valuable. Organizations everywhere should consider it their moral duty to filter out irrelevant information and dark data. The public, the Government and the industry needs to be made aware of the environmental risks associated with the massive storage of redundant and dark data. Therefore, society must realize the value of working together to reduce the environmental impact of storing dark data so as to avoid taking an irreversible turn towards an unsustainable digital future. Preventing climate change and preserving long-term sustainability depend heavily on people adopting ecologically conscious online behavior[xxii]. Fostering sustainable digital behavior requires educating Internet users about the negative effects of their online actions as well as the benefits of small behavioral adjustments through information campaigns, behavioral nudges and other strategies. Because cloud storage is so accessible and affordable people store thousands of digital photos and movies on their computers that they never watch. In addition, people should be mindful of unread emails, instant messages, documents, spreadsheets, and presentations. They should also keep track of the information they have saved over time. It is possible to reduce the environmental impact of Internet use by taking small steps like unsubscribing from email lists, clearing out emails and unnecessary content from cloud-based storage services and turning off videos during online meetings. Just using a smartphone to snap a picture and sharing it on social media creates two different kinds of dark data: the post itself, the image and the metadata that

surrounds it. Comparing the metadata to the amount of data in the image itself it is essentially insignificant[xxiii]. People are currently encouraged to continuously upload and share content in order to generate data that advertising algorithms can use to target them. This data also feeds into other machine learning projects among other things. However, businesses and individuals worldwide need to manage their data on a daily basis to prevent the creation of dark and redundant data or its deletion for the benefit of the environment.

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