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# SUSTAINABLE DATA CENTERS:
# POWERING THE DIGITAL REVOLUTION

Digital Climate Alliance

## SUMMARY

Data centers are an integral part of modern-day society as they store and process massive amounts of data, from personal information to business data, and everything in between. However, data centers also consume an enormous amount of energy and have a significant impact on the environment. With the growing demand for data storage and processing, it is critical to address the need for sustainable data centers that can reduce their environmental impact while still meeting the growing demand for data. This paper aims to explore the importance of sustainable data centers, their impact on the environment, and potential solutions to reduce their carbon footprint. The timeliness of this paper cannot be overstated, as the demand for data continues to grow exponentially, and the environmental impact of data centers remains a pressing concern.

## THE DIGITAL CLIMATE ALLIANCE

Autodesk, Baker Hughes, Black & Veatch, Dell Technologies, Intel, Nautilus Data Technologies, Schneider Electric, Trane Technologies

As more and more companies leverage digital technologies to reduce climate impacts, improve energy and water efficiency and resiliency, and drive further innovation across our nation's critical infrastructure, there needs to be a concerted voice coordinating these efforts and advocating for the increased use of digital technologies as solutions to addressing the climate crisis. The Digital Climate Alliance is a coalition of companies developing and utilizing digital technologies to reduce their environmental impacts for themselves and for their customers. The Digital Climate Alliance's goal is to promote digital technologies to enable 21st century solutions, solving climate, water, and energy challenges that impact economic development, business growth, social well-being, and ecosystem health.

## ACKNOWLEDGEMENTS

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Learn more at www.co2efficient.com.

## TABLE OF CONTENTS

## INTRODUCTION

The rise of the internet has been a massive driver of economy-wide systems change, transforming social relationships, global connectivity, science, politics, entertainment, jobs, and more. Global internet traffic has increased exponentially over the past few decades (see Figure 1).

The Digital Age is rapidly evolving, and the internet and digitalization now play a critical role in daily life and the global economy.[2] Serving as the information backbone of this new era, data centers are essential.

From communication, finance, e-commerce, and cloud computing to social media and streaming video, we rely on data centers – facilities that house equipment for storing, processing, and disseminating data – to handle vast amounts of information quickly and reliably in our daily activities.[3]

Data centers are also necessary to support a healthy U.S. economy.[4] Looking ahead, growth in internet traffic and digitalization is only projected to accelerate. Activities such as video streaming, virtual reality applications, and cloud gaming are data-intensive and are expected to increase significantly.[5]

Artificial intelligence (AI), machine learning, blockchain, the proliferation of connected devices ("the Internet of Things" or IoT), and other emerging technologies are also expected to further amplify data center demand. For instance, the number of global IoT connections grew 8% in 2021 to 12.2 billion active endpoints; the number is projected to grow to 14.4 billion in 2022 and to approximately 27 billion by 2025.[6] This proliferation of connected devices will drive IoT data processing demand.

### WHAT ARE DATA CENTERS?

A data center is a facility used to house and manage computer systems and associated components, such as telecommunications and storage systems. It provides a secure, temperature-controlled, and power-managed environment for critical computing infrastructure, such as servers, routers, switches, and storage devices.

Data centers are designed to support the reliable and secure operation of information technology (IT) equipment and applications. They typically have redundant power and cooling systems, backup generators, and advanced security measures to protect the equipment and data stored within them.

Enterprise data centers are owned and operated by a single organization, businesses, or government. Hyperscalers are companies that provide cloud computing services to a global audience. They operate massive data centers that are designed to handle the needs of millions of users and are typically located in strategic locations around the world. Smaller organizations may use third-party data center providers to host their IT equipment and applications, rather than investing in their own data center infrastructure.

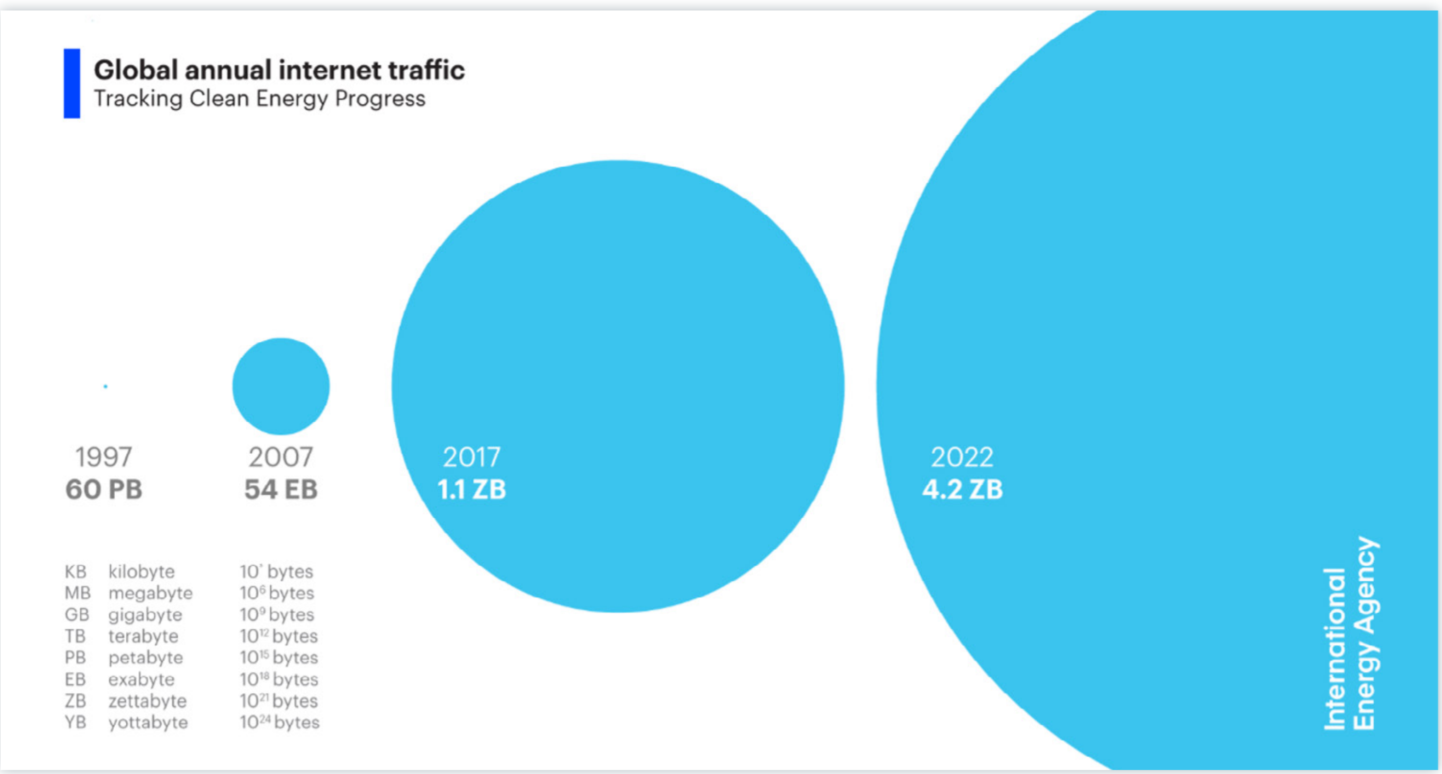


***Figure 1**: Growth in Global Internet Traffic (Source: International Energy Agency[1])*

*The Internet of Things refers to a network of physical devices, vehicles, home appliances, and other items that are embedded with sensors, software, and connectivity, enabling them to interact and exchange data with each other and with other systems over the internet. Endpoints are the "things" that connect to a network system such as mobile devices, desktop computers, virtual machines, embedded devices, and servers.*

The popularity of applications that use distributed ledger technology to securely store information is increasing – one of the many demand drivers for even greater data center capacity. Edge computing can help meet some of the demand for these emerging digital services by enabling on location data processing in areas with limited internet connections, highly sensitive data, or large datasets that may be too expensive to send to the cloud.[7] However, beyond these specific cases, there will be increased demand that can only be met by increasing data center capacity. As such, the data center construction market is projected to grow 9% in the U.S. and 11.2% worldwide between 2020 and 2025.[8]

As data demands increase and connected devices proliferate, it is imperative that efforts accelerate to minimize data centers' environmental footprints, while also maximizing their beneficial "handprints," which enable other industries to reduce their energy, water, and climate footprints. This paper:

- Reviews some of the sustainability challenges and opportunities confronting data centers as data and workload demands grow.
- Describes measures that data center operators are adopting and some of the challenges they face going forward.
- Concludes by highlighting existing policy actions that promote data center sustainability, as well as some of the enhanced policies needed to further drive sustainability as the world races forward into the Digital Age.

## WHAT IS CLOUD COMPUTING?

Cloud computing is the use of remote servers on the internet to store, manage, and process data, instead of using a local server or a personal computer. It involves multiple users sharing resources such as applications and storage over the internet in an efficient manner. Cloud computing allows businesses to access services like applications, databases, and servers without having to buy and maintain expensive equipment. Cloud computing services are typically provided by third-party providers who own and maintain the necessary hardware and software infrastructure.

## SUSTAINABILITY CHALLENGES & OPPORTUNITIES

As computing demand continues to grow exponentially, the resource-intensive nature of some data centers may become a more significant challenge. The development and operation of data centers requires substantial amounts of electricity and water. Additionally, consistent equipment upgrades contribute to the growing problem of electronic waste.

Data centers consume roughly 10-50 times more energy per square foot than a typical office building.[9] The International Energy Agency (IEA) estimated that data center electricity usage in 2021 accounted for roughly 1% of global electricity demand, not counting energy use from cryptocurrency mining, and that data centers and data transmission networks accounted for just under 1% of energy-related greenhouse gas emissions and about 0.6% of all greenhouse gas emissions.[10]

Data centers also consume millions of gallons of water, both directly (e.g., for cooling) and indirectly (e.g., in producing the electricity that data centers use). In 2018, the total annual operational water footprint of U.S. data centers was estimated at 5.13 × 10 to the 8th cubic meters, which is approximately 34 billion gallons, making the data center industry one of the nation's top ten water consuming industrial or commercial industries.[11] Data centers, whether directly or indirectly, draw water from about 90% of U.S. watersheds,[12] and some data center operators may draw more than half their water from potable sources.[13]

In addition, as data centers continually upgrade equipment to enhance capacity and improve efficiency, this contributes to the global challenge of electronic and electrical waste. According to the United Nations Environment Programme, the world produces roughly 50 million tons of e-waste a year – less than 20% of which is formally recycled – and is on pace to reach 120 million tons per year by midcentury, causing not only health and pollution impacts, but also the loss of valuable raw materials.[14] In 2017, the U.S., according to the Global E-Waste Statistics Partnership, generated 6.918 kilotons [7.62 million tons] of e-waste, 15% of which was collected and recycled.[15]

While data centers have environmental footprints, they also have beneficial "handprints" – they enable other industries to reduce their energy, water, and climate footprints. For example, government initiatives to expand clean energy and vehicle electrification, as well as corporate and industry initiatives to make progress toward net-zero emissions goals, depend on digital technologies, data analytics, and a range of software and systems. All of these rely on data centers to manage the vast amount of information involved.[16] By underpinning the shift toward sustainable practices, data centers will enable information and communication technologies (ICT) to reduce global greenhouse gas emissions by a projected 6-12% by 2030.[17] Likewise, digital technologies supported by data centers can help improve water resource management and use.[18]

BLACK & VEATCH
EMPLOYEE-OWNED

### BLACK & VEATCH WATER MANAGEMENT

Black & Veatch offers data center clients water solutions on the forefront of conservation and innovation. Black & Veatch evaluates water demand, assesses all possible water sources (including brackish water, seawater, and reclaimed water), and considers various water management options and solutions (e.g., with respect to cooling technologies and water quality & treatment) to help data center clients make smart and sustainable water decisions.

*See Black & Veatch, "Water Management for Data Centers", https://webassets.bv.com/2020-10/20%20Water%20Management%20for%20Data%20Centers_WEB.pdf*

intel

### INTEL IMMERSION LIQUID COOLING

Intel has introduced the industry's first open intellectual property (open IP) immersion liquid cooling solution and reference design — an easy-to-deploy and easily scalable total cooling solution. Intel is also investing in a state-of-the-art mega lab in Oregon focused on innovative data center technologies such as immersion cooling, water usage effectiveness, and heat recapture and reuse.

*See Intel, "Intel Makes Key Investments to Advance Data Center Sustainability", May 19, 2022, https://www.intel.com/content/www/us/en/newsroom/news/key-investments-advance-data-center-sustainability.html#gs.ep65w3*

## EFFORTS & TECHNOLOGIES TO IMPROVE DATA CENTER SUSTAINABILITY

Increasingly, data center operators are taking action to reduce their footprints and improve data center sustainability.[19] One of the most notable areas of effort has been ***energy efficiency***. For example, while data demands have grown exponentially over the past 25 years[20] and global internet traffic more than tripled over the past 5 years,[21] data center energy consumption globally hardly changed between 2010 and 2020 (see Figure 2).

This trend is due in part to efficiency improvements in servers, chips, and other hardware. Servers, for example, have seen improvements in their power scaling abilities, reducing power consumption during idle or low-utilization periods. A typical server uses about a quarter of the energy compared to what it would have in 2010, while storing data takes about a ninth of the energy.[23] Likewise, improvements in chip technologies have quickened processing and data transport and reduced heat and electricity needs. The energy efficiency trend has also been driven by a shift from smaller data centers to more efficient hyperscale data centers. Typically, hyperscalers or cloud data centers are more efficient than enterprise data centers, which are better than server cabinets.[24]

Schneider Electric

### SCHNEIDER ECOSTRUXURE EFFICIENCY

Schneider Electric's EcoStruxure Platform, which is at the heart of its IoT system architecture, enables data centers and other facilities to maximize energy efficiency and sustainability by bringing together power, cooling, management, and other operational elements. EcoStruxure connects a range of products and systems, collects and tracks data on energy usage and other metrics, and uses software and analytics to increase efficiency and track sustainability progress.

*See Schneider Electric, "EcoStruxure™ Data Center Solutions and Networks",* https://www.se.com/us/en/work/solutions/for-business/data-centers-and-networks/

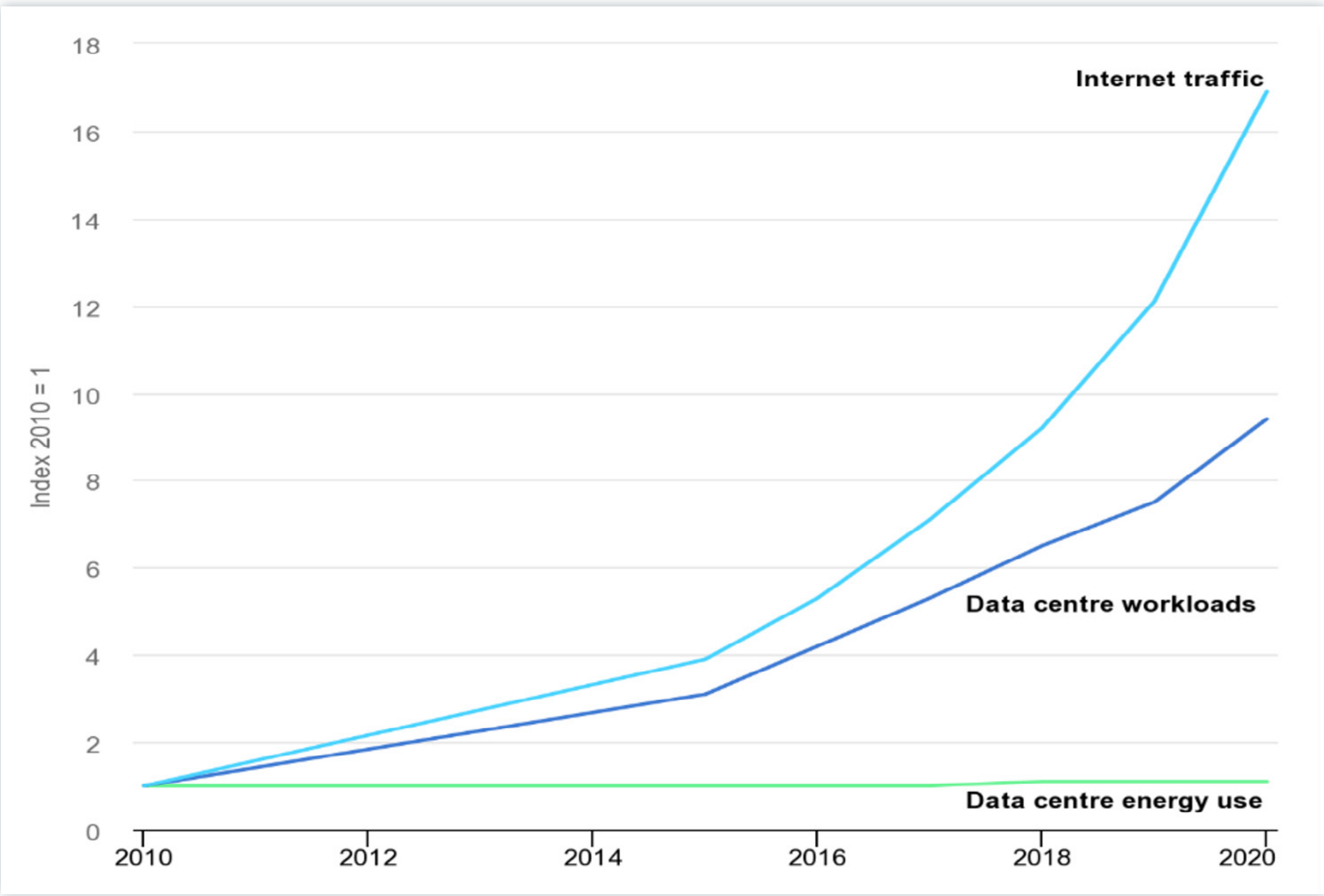


***Figure 2****: Global trends in internet traffic, data center workloads, and data center energy use, 2010-2020 (Source: International Energy Agency[22])*

ICT companies – particularly hyperscale data center operators – have also been the leading corporate purchasers of ***clean energy*** (see Figure 3).

Purchasing clean energy does not necessarily mean that data centers are powered by electricity from 100% clean sources, but the purchases support clean energy around the world. Some leading ICT companies have also announced targets to match zero-carbon electricity to their actual demand 24/7 within the grids where their facilities are located.[26] Cloud data centers are increasingly able to support clean energy sources where they are located, including next-generation geothermal energy.[27] In addition, methods such as carbon-aware computing are starting to enable data centers to shift flexible tasks to different times of the day or different locations to maximize the use of carbon-free electricity.[28]

Data centers are pursuing additional sustainability improvements as well, including measures to enhance ***water conservation and stewardship***. Data centers are reducing strain on water supplies through innovative partnerships and alternative sourcing, such as using brackish water, seawater, or reclaimed wastewater for cooling.[29] Data center operators are also increasing water efficiency to minimize their water needs, such as by recirculating water multiple times through cooling systems rather than using a "once through" approach or, in some cases, eliminating the need for water in cooling systems entirely.[30]

Baker Hughes

## BAKER HUGHES MICROGRIDS

Baker Hughes offers a range of technologies that could be used to create net-zero microgrids to support data centers in remote environments. One approach includes using battery storage, advanced energy management systems to optimize the use of clean energy, and NovaLT gas turbines that could be paired with carbon capture or could utilize up to 100% hydrogen. Such a system could ensure reliable power while minimizing carbon emissions.

*See Baker Hughes, "Baker Hughes and Bloom Energy to Collaborate on Efficient Power and Hydrogen Solutions to Accelerate Energy Transition", May 5, 2021, https://investors.bakerhughes.com/node/25281/pdf*

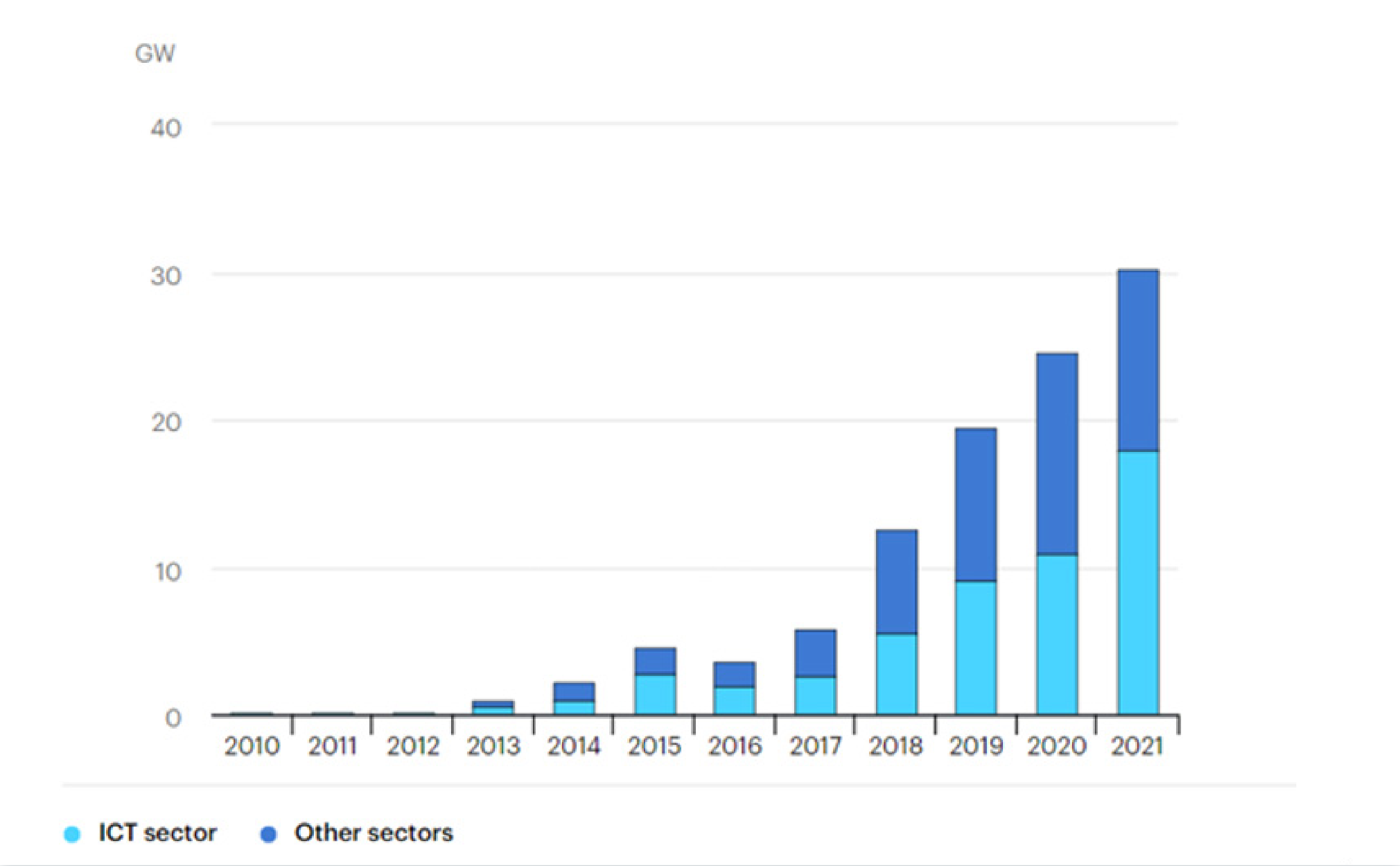


***Figure 3****: Global renewable energy power purchase agreements by sector, 2010-2021 (Source: International Energy Agency[25])*

Data center operators are simultaneously pursuing liquid cooling designs and other solutions to reduce the energy and water needed for data center cooling.[31] For example, with immersion cooling, servers are kept completely immersed in a liquid that absorbs all the heat they generate, which can then be used or routed elsewhere; an immersion cooling system could reduce not only data center energy use, but also water consumption (by more than 90%). [32]

Nautilus Data Technologies patented a cooling technology utilizing a water-based heat sink for its data centers located near or floating on any body of water; such a system enables liquid cooling designs, like immersion or direct-to-chip, while improving net energy efficiency by 30%, reducing carbon emissions by 30%, and eliminating all water consumption, water treatment chemicals, and chemical refrigerants.[33]

Waste heat captured by various types of cooling systems, particularly liquid cooling designs, can be reused, either by the data center itself or by others nearby, thereby reducing the need for additional energy inputs. Data center operators are increasingly exploring ***heat reuse*** possibilities, such by connecting to district heating systems.[34]

To address e-waste and advance a more ***circular economy***, data center operators are increasingly working to enhance product longevity and responsibly decommission, reuse, and recycle data center hardware assets. Some leading ICT companies are accelerating efforts to use refurbished inventory for server upgrades, divert waste from global data center operations away from landfills, recycle critical parts, and resell components into the secondary market.[35] For example, when Dell rotates in new technology assets, 95% are refurbished and remarketed, with the remainder recycled.[36]

NAUTILUS® DATA TECHNOLOGIES

## NAUTILUS WATER COOLING TECHNOLOGY

Nautilus Data Technologies is leading the charge in sustainable, high performance infrastructure with water-cooled data center solutions. Nautilus' proprietary technology utilizes a water-based heat sink to eliminate any water consumption, removes the need for chemicals and refrigerants altogether, and reduces energy consumption by 30% in the data center. Meanwhile the system enables higher density compute for artificial intelligence and machine learning technologies. The first data center, commissioned and operating with multiple tenants - including Backblaze - is at the Port of Stockton in California and has exhibited no negative impact on wildlife while fully meeting the state's rigorous environmental regulations.

*See Backblaze, "Backblaze Rides the Nautilus Data Center Wave", Sept. 8, 2022, https://www.backblaze.com/blog/backblaze-rides-the-nautilus-data-center-wave/*

TRANE TECHNOLOGIES™

## TRANE HEAT RECOVERY SYSTEM

Trane Technologies collaborated with the Aalsmeer Energy Hub in the Netherlands to provide a custom electric heat recovery system to capture and recycle heat generated by NorthC Datacenters as a source of heat for nearby facilities, including a sports complex, a childcare center, and a plant nursery. The heat reuse solution avoids nearly 400 metric tons of $CO_2$ emissions per year.

*See Trane Technologies, "Sustainability in Action: The Aalsmeer Energy Hub", Mar. 15, 2022, https://blog.tranetechnologies.com/en/home/solutions-innovation/the-aalsmeer-energy-hub.html*

While all these efforts and technologies improve data center sustainability, much more can be done. Many practices, such as heat reuse, are not yet widespread. As noted earlier, the accelerated emergence of cryptocurrency, AI, machine learning, blockchain, IoT devices, and other technologies are expected to cause increased data center demand. While data centers have been utilizing energy efficiency measures, moving forward, they will need to adopt more efficiency measures regarding equipment, cooling, lighting, and other elements of data center operations.[37] The same is true regarding water efficiency and sourcing, especially since many data centers are located in water-stressed areas that will become even more water-stressed as climate change progresses.[38]

Data centers are the backbone of the Digital Age and are necessary to support a healthy U.S. economy. While data center operators will keep striving to improve sustainability, they cannot achieve their sustainability goals by themselves. There is a role for the federal government to help make data centers more sustainable. Federal policies should drive energy efficiency, heat reuse, sustainable water sourcing, generation, and adoption of clean energy, as well as provide support for research on alternative cooling methods and other aspects of data center sustainability.

DELL Technologies

## DELL TECHNOLOGY ROTATION

Dell provides clients, such as a Ficolo data center in Finland, with *Technology Rotation*, a flexible pay-as-you-go payment solution, which rotates new technology assets in and obsolete equipment out at a pre-defined cycle. In addition to enabling improved reliability, scalability, security, and cost savings, *Technology Rotation* contributes to the circular economy by refurbishing and remarketing 95% of assets — which are put back into productive use — and recycling the remaining 5% in adherence with local regulatory guidelines.

*See Dell Technologies, "Deploying State-of-the-Art Cloud Data Centers", Jan. 26, 2022, https://www.dell.com/en-us/blog/deploying-state-of-the-art-cloud-data-centers/*

AUTODESK

## AUTODESK MODELING FOR SUSTAINABLE DESIGN

Autodesk's Building Information Modeling (BIM) tools, such as Revit and AutoCAD, can be used to design and plan more sustainable data centers by allowing for virtual simulations and analysis of building performance. This can help optimize energy usage throughout the life of the buildings, identify potential issues, and plan for efficient use of resources. BIM can also be used to collaborate with other team members, such as architects, engineers, and contractors, to ensure the data center is designed and built in a way that is sustainable.

*See Autodesk, "Building Information Modeling", https://www.autodesk.com/industry/aec/bim*

## POLICIES TO HELP IMPROVE DATA CENTER SUSTAINABILITY

Federal policies can play a critical role, catalyzing data center sustainability.

There are existing federal policies and government programs that will help improve data center sustainability.[39] For example, the Energy Act of 2020 required an updated study on data center energy and water usage, development of a metric for data center energy efficiency, and maintenance of a data center energy practitioner program.[40] The U.S. Department of Energy's (DOE) Federal Energy Management Program (FEMP), through its Center of Expertise for Energy Efficiency in Data Centers, helps agencies and organizations construct and maintain energy efficient data centers by providing resources and encouraging participation in federal programs (e.g., the Better Buildings Challenge and Data Center Accelerator).[41] There are also other programs and regulations to drive improved energy efficiency in servers and other data center components, including ENERGY STAR in the U.S.[42]

As demand for data centers continues to grow, there is an opportunity for the federal government to develop policies catalyzing their sustainability. These policies should include:

1. **Enable "as-a-service" models for the public sector, including addressing barriers at the federal, state, and local levels.**
    - *Identify and examine barriers limiting the ability of federal agencies, state and local governments, and other public sector entities to leverage cloud-based and hybrid cloud-based services.* Organizations that provide these services can frequently provide them at a lower carbon intensity than is achievable within government data centers.
    - *Conduct information campaigns on carbon-aware cloud computing for policy makers, providers, companies, and universities.* Carbon-aware computing enables data centers to shift flexible tasks to different times of the day or different locations to maximize the use of carbon-free electricity. To maximize the emission-reducing potential of carbon-aware computing, more developers and customers need to be made aware of it. There are some efforts along these lines from the Green Software Foundation and others,[43] but governmental entities (e.g., FEMP) can play an important role in raising awareness.
    - *Include energy efficiency for cloud computing in national digital policy initiatives.* Some countries are adopting national strategies to guide them as they move further into the Digital Age. National policies to advance digitalization should include a clear focus on fostering energy efficient data centers and cloud services.[44]
2. **Identify the next generation of performance metrics, trends, and improvements to develop the baseline for future policy actions.**
    - *Direct the national laboratories to conduct additional research and continue working with industry to develop an information technology (IT) equipment energy efficiency metric for measuring the work output per unit of energy of a data center.* Metrics are needed for data centers as a whole, not just measurements of the work outputs of individual server, storage, and networking equipment.
    - *Develop performance standards.* Though some initial work has been done, industry and the federal government do not have a robust set of indicators to gauge and compare data center sustainability performance, though some initial work has been done.[45] The federal government should work with The Green Grid and other forums to engage data centers on the development of performance standards. For example, policymakers could consider developing minimum energy performance standards for servers and data storage products.[46]
    - *Direct federal agencies and the national laboratories to develop metrics to quantify a data center's handprint.* Data centers provide the foundation for the transformational changes that the internet and digitalization brought in social relationships, global connectivity, jobs, and now, sustainability. DOE, working with other federal agencies and national laboratories, should develop a standards-based methodology and metrics to quantify the handprint of data centers.
    - *Direct increased methodologies and metrics on key performance indicators to accurately measure sustainability efforts.* The federal government should provide standardized methodologies to help data center operators better track and share data on sustainability performance, including energy consumption and the percentage of zero-carbon energy consumed.[47]
3. **Promote research and development (R&D) on data center power and cooling efficiency.**
    - *Increase funding for R&D.* Support by the federal government is needed to facilitate R&D on alternative cooling methods, materials and devices that improve hardware efficiency, and other aspects of data center sustainability to ensure such technologies are effective, affordable, and widely available as data center demand surges.[48] For example, the Advanced Research Projects Agency–Energy (ARPA-E) in September 2022 announced more than $40 million in funding to help develop high-performance energy efficient cooling solutions for data centers, as part of its broader COOLERCHIPS data center cooling innovation program.[49] This is a model that should be replicated more widely to tackle the suite of data center sustainability challenges.

- *Identify data center operation best practices and encourage utilization.* As the demand for data centers continues to grow, it is crucial to prioritize efficient and sustainable operations. The federal government, in collaboration with industry leaders, should identify and promote best practices that prioritize energy efficiency and sustainability. This effort should also consider emerging technologies such as liquid cooling and explore existing barriers limiting widespread adoption of these practices. The goal is to encourage the adoption of these best practices and promote the long-term sustainability and efficiency of data center operations.

- *Require evaluations of heat reuse potential.* Data centers over a certain size should be required to conduct assessments and publish reports on waste heat utilization opportunities.[50] In addition, policy makers should collaborate with data center operators and district heating suppliers to develop appropriate incentives, guarantees, and other measures to overcome barriers to waste heat utilization.[51]

4 **Develop a sustainability roadmap for the data center industry focusing on decarbonization, water, and energy.**

- *Increase funding and incentives to promote a circular economy.* Measures to support durable product design, producer buy-back and return systems, and efforts to extract useful metals and minerals from e-waste could help address e-waste and advance a more circular economy. Agencies such as DOE and National Science Foundation, for instance, already fund some research related to recovering metals and minerals from e-waste,[52] but such efforts are not yet commensurate with the scale of the challenge.

- *Increase incentives to drive energy efficiency, heat reuse, and sustainable water sourcing.* Incentives could take several forms, including grants and tax measures.[53] Additional incentives are necessary to address the full spectrum of sustainability challenges confronting data centers.

- *Promote utilization of clean energy for data centers.* The federal government should ensure existing programs and funding are being effectively utilized to increase opportunities for data centers to procure clean energy.

## CONCLUSION

Data centers are the information backbone of the rapidly evolving Digital Age, but supporting tomorrow's digital solutions requires greening the data centers that will run them. Data center operators are already pursuing efforts to enhance energy efficiency, clean energy, waste heat utilization, water conservation, and other sustainability efforts. As demand surges, however, data center operators need partners in the federal government to develop policies to assist catalyzing data center sustainability.

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