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Where Climate Meets Digital

Data Centers and Sustainability

Data Centers and Sustainability – Where Climate Meets Digital

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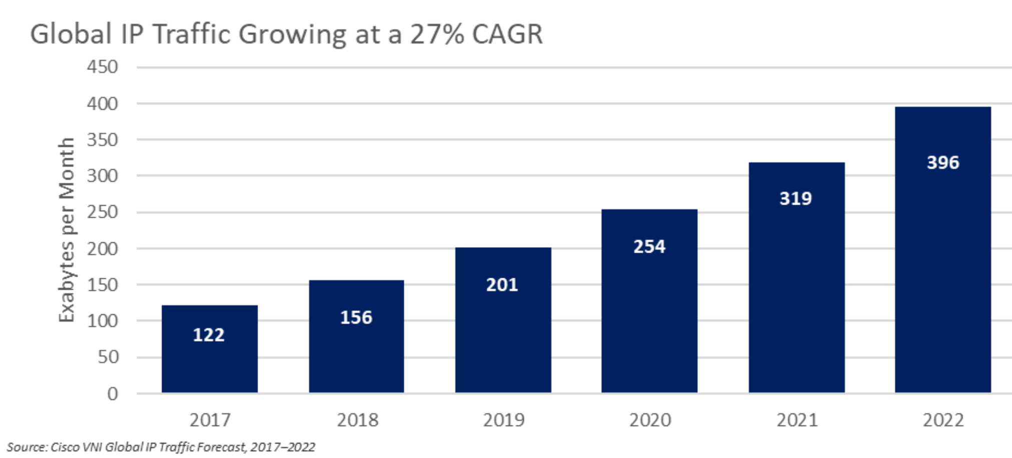
A data center is the meeting point of two key global trends– the fast-paced growth of the digital economy and the global push for sustainability. The data-driven Fourth Industrial Revolution is accelerating at the same moment our civilization is coming to terms with how we're fundamentally changing the planet. We need new infrastructure to process and store the massive amounts of data we're constantly generating, and we need it fast – but we also need that infrastructure to have as little impact on the environment as possible, and we need it to run for decades despite a changing climate. Managing that conflict is the key challenge for data center design and construction.

AVAIO Capital is a seasoned group of infrastructure and private equity professionals that seek to invest in de-risked, mid-to-late stage sustainable real asset creation and re-development & expansion opportunities. We take sustainability and resiliency into account in every step of our project development process. AVAIO has a strategic partnership with AECOM, the global design and engineering firm.

To put digital growth in perspective – Cisco now forecasts that annual data traffic will double by 2022[1], when it's expected that more data will cross global networks in a single year than in the entire 30-plus years since the creation of the internet combined. That 4.8 zettabytes – or 4.8 *trillion* gigabytes - of expected 2022 traffic is the equivalent of every movie ever made moving across the internet every minute[2].



Handling, transferring and storing these data – and keeping servers cool and operating efficiently – requires a lot of power. In 2017 data centers in the US alone used more than 90 billion kilowatt-hours of electricity, equal to the output of 34 power plants of 500 megawatts (MW) each[3]. If all

[1] Thomas Barnett et al., "Cisco Visual Networking Index (VNI) Complete Forecast Update, 2017-2022," Dec 2018
[2] "Cisco Predicts More IP Traffic in the Next Five Years Than in the History of the Internet", Cisco Nov 2018
[3] Danilak, Radoslav, "Why Energy Is A Big and Rapidly Growing Problem For Data Centers," Forbes, Dec 2017

those plants were coal-fired, they'd have pumped out over 100 million tons of carbon dioxide - more than 2% of the CO_2 produced by the entire US economy in 2018. Worldwide, annual data center power demand is now over 200 terawatt hours[4], about 1% of the world's total power consumption and equal to about 5% of Europe's total power output last year. Given the growth rates expected in IT infrastructure, sustainably managing data center power demand is only going to get more challenging.

We see **four key elements** to data center sustainability. First, power usage **efficiency** – the greenest electrons are those that are never generated in the first place, so minimizing the power needed to run a data center is the best way to reduce its impact. Second, the source of that power – running a data center on **renewable energy** lowers its carbon footprint. The proper handling of data center **water** use and **waste** creation– whether heat, water or used IT equipment – are key sustainability metrics. And finally, siting, designing and constructing data centers to be more **resilient** can prolong their lives and help to reduce the risks from a changing climate.

As demand for data centers picks up, so do the pressures – environmental, financial and regulatory – to develop them in a sustainable way. A successful strategy needs proper attention to all these elements.

Efficiency – Saving Money, Cutting Carbon

The typical data center runs 24/7 for 365 days of the year, or a total 8,766 hours. In a market with average electricity rates of $0.05 per kWh, the annual cost of power is about $438 per kW. For a 25 MW data center that comes to nearly **$11 million per year** in expenses, or **$164 million** over 15 years of continuous operations.

One of the key drivers of that power draw is cooling. Although performance is constantly improving, servers are still highly sensitive to temperature and humidity, and their processing power drops as they get hotter, so keeping them cool is a top priority. But energy losses through the data center's cooling system can be a significant percentage of the total power demand. Hence the notion of the **Power Usage Efficiency (PUE)** metric – effectively the ratio between the total power used by a data center divided by the power used solely for computing. The closer to 1.0 that ratio is, the more efficient the system.

$$\text{PUE} = \frac{\text{The total power used by the data center}}{\text{The power used by its IT equipment}}$$

The example above shows how critical PUE can be – a data center that needs 25 MW to run its IT equipment and has a PUE of 1.67, the industry average in 2019[5], needs nearly 42MW of total

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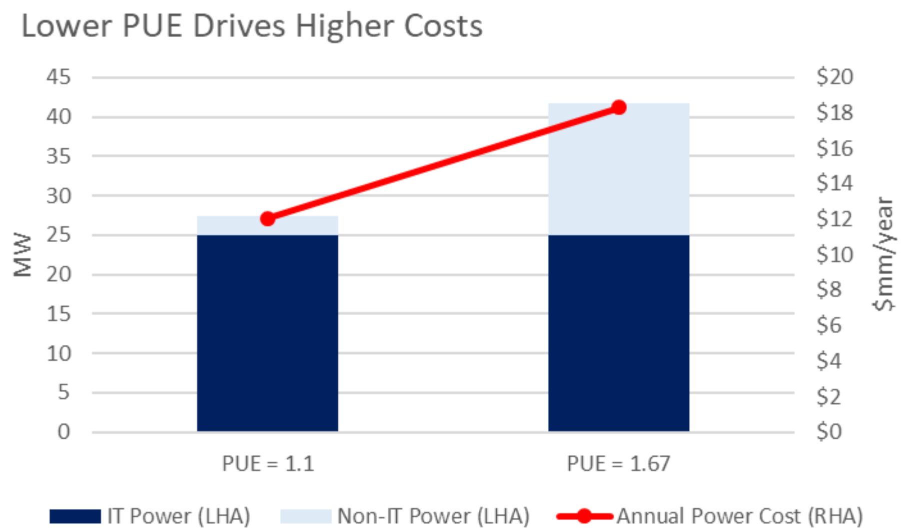
[4] Jones, Nicola, "How to Stop Data Centres From Gobbling Up the World's Electricity", Nature, Sept 2018
[5] https://journal.uptimeinstitute.com/is-pue-actually-going-up/

power to operate. Meanwhile Google's most efficient data centers are running at PUEs closer to 1.1[6] – at that level, a 25MW IT load would only require 27.5MW total power. Assuming a $0.05/kWh power price, that difference in PUE would make for annual savings of more than **$6mm** – or a total **$94mm** over a 15-year lease.



And those are just the cost savings to the operator – again, if these data centers are pulling coal-fired power off the grid, that difference in efficiencies is equal to about **90,000 tons** of annual CO2 emissions – about the same as **20,000 new cars** on the road[7].

Operators have multiple paths to make their data centers more efficient. Better **temperature management** can save significant power – modern servers can operate at higher temperatures, and every degree Fahrenheit increase in a data center's operating temperature can bring a 2-4% drop in energy use, depending on the system[8]. Careful maintenance of temperature set points can directly boost the bottom line, and operators are maximizing their control over real-time monitoring – Google has introduced a new artificial intelligence algorithm to monitor a data center's cooling system every five minutes, choose the most efficient cooling configurations and adjust the system accordingly[9].

Recent research suggests that more than a quarter of servers in US data centers are **"zombies"** - servers that are drawing power but no longer being used for computing[10]. New software solutions can ferret out these comatose servers and make it easier to shut them down without affecting active operations, saving significant power and making better use of limited space.

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[6] https://www.google.com/about/datacenters/efficiency/internal

[7] US EPA (2014) - Greenhouse Gas Emissions from a Typical Passenger Vehicle

[8] Via AECOM Design Consulting Services proprietary customer calculations

[9] MIT Technology Review, August 2018 - Google Just Gave Control Over Data Center Cooling to an AI

[10] Koomey, J, and J. Taylor (2017) – Zombie/Comatose Servers Redux

The choice of **power equipment** and how it's configured can have a huge impact. Typically a data center's power is drawn from the grid, and the way that power is delivered from the street outside to the servers involves multiple steps and transformations. Older versions of the Uninterruptable Power Supply (UPS) systems that data centers use to maximize reliability would often switch incoming power from AC to DC to charge batteries, then back to AC to support the servers. This conversion is complicated by the rise of DC solar, fuel cells and other on-site power sources. Newer UPS systems can either bypass this double conversion, improving efficiencies, or use alternate configurations like placing batteries at the server racks where their charging and discharging can be more closely aligned with the servers' needs. Either of these solutions can not only drive power savings up to as high as 10%, but reduce the space needed for batteries.

The Design Consulting Services arm of AECOM, AVAIO's strategic partner, is at the forefront of data center efficiency optimization, with a design approach to cooling and power that draws on the deep knowledge of the broader AECOM Energy Efficiency practice

Careful attention to temperature, power storage dynamics and unnecessary server usage are relatively low-cost ways to improve data center efficiencies – not only saving costs but CO_2.

Renewable Power – From Nice-to-Have to Must-Have

Power is the defining metric of the data center industry. Data center sizes are quoted not only in square feet but in megawatts (MW) – the simplest measurement of computing capacity. As noted above, the amount of power that data centers are drawing globally, and the volume of emissions associated with that power when it comes from burning fossil fuels, is only growing as data usage climbs.

Data center power purchasing has evolved as end users have increasingly emphasized sustainability. In the early days of the internet, users simply bought whatever power was available off the local grid, with little to no thought as to how that power was produced – from coal, gas, nuclear or renewable. That began to shift as the amount of power used by data centers increased and the big tech companies became increasingly aware of the contribution of their operations to carbon emissions.

In many cases these companies set themselves renewable power targets that are more aggressive than even the greenest goals of governments: In 2011 Facebook was the first tech company that committed to **100% renewable energy** across its operations, closely followed by Apple and Google in 2012 and Amazon Web Sevices (AWS) and Microsoft in 2014. Today, as signatories to the RE100 intiative, over 190 companies have made date-certain commitments to sourcing all of their power from renewables. Data center end users and colocation companies ("colos") were pioneers in this effort.

Initally many data center users met their renewable goals through **virtual power purchase agreements (VPPAs)**, under which an offtaker agrees to buy the power from a specific renewable project at a pre-agreed price for a specified time (generally 10 years or more). VPPAs are offsets - the actual electricity from the power project never makes it to the buyer; instead the end user simply buys electricity directly from its local utility grid, while the renewable project developer sells its energy at market prices. The VPPA buyer and the renewable project developer then financially settle the difference between the agreed VPPA price and the market price, and the buyer receives any renewable energy credits (RECs) generated by the project.

As an example, data center colo Digital Realty recently signed an agreement with developer SunEnergy1 to buy 80MW of power from a new North Carolina solar farm. Digital Realty is buying the power on behalf of its tenant Facebook, which will receive the RECs generated by the project, and the long-term agreement finances SunEnergy1's project development. VPPAs can create a win-win, in which developers get support to build new renewable energy projects while the buyer gets to hedge its power pricing, reap the benefits of the RECs and point to new clean energy it helped to bring online.

A downside of VPPAs is that, unless the project selling the power is on the same grid as the buyer, that new renewable project isn't displacing "dirty" energy. So, tech companies and other green-conscious corporates are increasingly supporting the construction of new renewable energy within their own utility districts. These projects provide "additionality", bringing new renewable energy to the local grid that wouldn't necessarily exist otherwise:

- In March 2019, Microsoft and EDP Renewables signed a pair of 15-year power purchase agreements, under which Microsoft will be buying 125 MW of power directly from EDP's Timber Road IV windfarm in Ohio.
- Facebook's 40 MW data center in Prineville OR will be supported by PPA's with clean energy developers on the western grid, including from the 58 MW Cove Mountain Solar Project in Utah.
- Google's Hamina data center in Finland is powered via a PPA with three Finnish wind farms for a total 190 MW.

Google has taken its mandate a step further, targeting 24/7 carbon-free energy for all its operations, by measuring the percentage of renewable power from the grid is each region of operations and sculpting its own regional purchases of renewable power to ensure that there's enough clean power every hour of the day to cover its operations. In September 2019 Google announced the biggest corporate purchase of new renewable power to date, inking 18 new wind and solar deals for a total 1,600 MW across multiple regions.

The inevitable next step in this process is for the tech companies and corporate data center users to simply build their own renewable capacity, either right at their data center sites or within their utility service areas:

- Amazon Web Services is directly investing in new wind farms in the U.S. and Europe - a new 91.2MW wind farm off the coast of Donegal, Ireland is expected online by the end of 2021 to serve AWS's data centers around Dublin. AWS also plans new wind farms near Tehachapi, California and Bäckhammar, Sweden that together will produce about 158MW.
- T5 Data Centers has formed a partnership with Atlanta solar developer Cherry Street Energy, under which T5's data center construction division will also install solar arrays – increasing the renewable options for T5's colo clients.
- Apple's 500,000 square foot "iDataCenter" in Maiden, North Carolina, the largest facility to earn LEED Platinum Status, has installed 48 MW of solar power in three arrays directly on the site along with 10 MW of biogas fuel cells.

Beyond these operational initiatives, many of the big tech companies have gone so far as to actively lobby for clean energy with host governments. Apple has filed comments with the US Federal Energy Regulatory Commission, urging the FERC to not pay subsidies to fossil fuel producers that could limit renewables' ability to compete in the electricity market. In Japan Apple has lobbied the Japanese government to create a renewable energy trading system, and along with Amazon, Google and Microsoft filed comments urging the US EPA to not repeal the Clean Power Plan. And these initiatives are not just from the top – in April more than 8,000 Amazon employees signed an open letter[11] to Jeff Bezos and Amazon's board to create a company-wide Climate Plan, including a call for a date certain to reach 100% clean power.

For data center developers, colo providers and data center facility owners, the provision of renewable energy has gone from a "nice to have" to a "can't live without" in their data center operations.

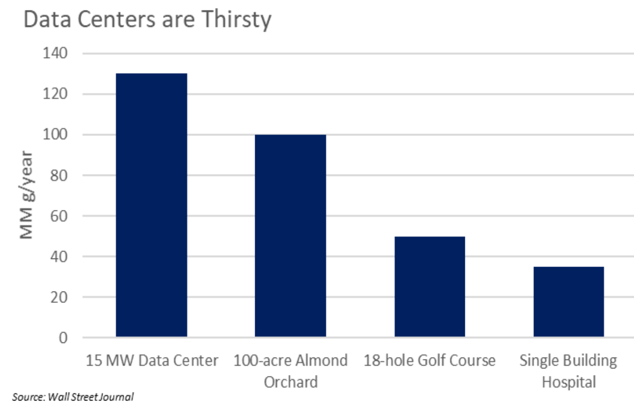
> *The multiple decades of experience of AVAIO's team in power and renewable energy – including in the development and operation of large-scale solar, wind and transmission assets - gives us powerful insight into best practices in power procurement and optimization, along with deep networks in the renewable energy sector*

Water & Waste Management – Driving the Circular Economy

Data centers are not self-contained units. In most operations, they draw in not only power but also water for cooling, and they generate heat, wastewater and electronic waste – all of which need to be actively managed to minimize projects' footprints.

[11] Amazon Employees for Climate Justice, April 2019 - Open letter to Jeff Bezos and the Amazon Board of Directors

In more and more locations the sheer volume of **water** required to cool servers has made water management and recycling a top priority for data center operators. A 15 MW data center can soak up more than **360,000 gallons** of water a day[12]; in 2014 it's estimated that US data centers collectively consumed about **165 billion gallons** of water[13]. Water is not only a direct cost but at these scales can be a burden on ancillary infrastructure, and designers need to be creative in its management.



Using water that's not suitable for other applications can lessen the strain on local services. Rainwater can be captured and stored for evaporative cooling or other non-potable purposes. Google's Hamina data center draws seawater from the Gulf of Finland for cooling using a free-flow, chemical-free heat exchanger system[14]. Municipal wastewater is another source that otherwise would be useless - Apple's 56 MW data center campus in Prineville, Oregon includes a plant that converts the city's wastewater into data center evaporative coolant, saving nearly five million gallons per year and offering Prineville a solution to what otherwise would be a disposal challenge. Proper metering of water consumption is crucial to better understand the viability of these options.

Wastewater can be a useful output as well - the city of Umatilla, Oregon plans to send wastewater from Amazon's data centers in the area to irrigation canals for local agricultural use[16]. Initiatives like this turn what would otherwise be a disposal cost into a public good.

No matter how efficient the design, any data center is effectively turning nearly all of the power it's drawing into **low-grade heat** that, in most cases, simply vents to the atmosphere.[17] Any use of that heat is added value, and can not only lower costs or boost revenue to the operator but can directly benefit other stakeholders.

Waste heat from the data center can be directly reused to provide low grade heating to the data center complex itself, saving on grid power. When waste heat from the data center cannot be directly reused because the temperature is too low, additional heat pumps can cost-effectively raise the temperature enough to run office, district, or other heating systems.

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[12] Hamilton, James, "Data Center Efficiency Summit Presentation," (April 2009).
[13] "United States Data Center Energy Usage Report," U.S. Department of Energy, June 2016
[14] "How Oceans are Being Used to Cool Massive Data Centres," Vice, Sept 2017
[15] "Apple will pay for Prineville water storage to meet data centers' enormous thirst," Oregon Live, December 2018
[16] "Umatilla To Reuse Data Center Water For Agriculture," East Oregonian, January 2018
[17] Monroe, Mark, "How to Reuse Waste Heat from Data Centers Intelligently," Data Center Knowledge, May 2016

Working with municipalities can be a win-win. Waste heat from Amazon's Tallaght data center in Ireland will be used the Dublin County Council to warm nearby homes and businesses[18]. The €15 mm system is Ireland's first data center-based district heating system and sets precedent for other hyperscale projects in urban areas.

Water and district heating are core AVAIO sectors, and AECOM has broad experience in designing and constructing these kinds of systems. AVAIO is working with some of the major tech companies on proposed water solutions for data center clusters, providing us with invaluable insights into optimizing data center water use and re-use

The next step in waste heat recycling is **reconversion back to energy**. Researchers at Rice University are working with carbon nanotubes to capture infrared radiation, or heat, and convert it to electricity in a process similar to solar photovoltaics[19]. As a solid-state system this would require less maintenance than a typical turbine converter and is potentially more efficient, effectively creating a feedback loop that recycles power.

Obsolete or discarded **electronic waste,** or **"e-waste"**, is an inevitable byproduct of the digitalization of the global economy. About 50 million tons of e-waste is produced worldwide every year, weighing more than all of the commercial airliners ever made, and only 20% of this e-waste is formally recycled.[20] On current trends global e-waste production is projected to reach 120 million tons per year by 2050.[21] Much of this ends up in landfills, potentially releasing pollutants into the environment, or is being recycled in ways that expose workers to hazardous substances like mercury, lead, and cadmium. Improper management of e-waste isn't only polluting but wasteful – e-waste can include valuable raw materials like platinum, gold, copper, nickel, cobalt, and other rare earth elements.

Data centers typically produce relatively small amounts of e-waste, but as they are being upgraded and expanded that's likely to change. Ensuring that the critical IT items are built for long lifecycles, and that they are repurposed before having to be recycled, will help mitigate e-waste growth. Strong regulations and guidelines are needed to make sure data center's relatively positive e-waste profile stays in place.

Resiliency – Building for a Changing World

As with all new infrastructure, data centers are being brought online in a world of accelerating climate change. While the internal servers of a typical data center are updated and replaced routinely, much of the critical equipment – including networks, cooling systems, the physical building itself – needs to be able to operate virtually around the clock for multiple decades, and

[18] "Excess heat from Amazon's giant data centre will be used to warm homes in Tallaght", The Journal, Nov 2018
[19] Williams, Mike "Rice device channels heat into light" – Rice University News, July 2019
[20] United Nations Environment Programme, "UN Report: Time to seize opportunity, tackle challenge of e-waste," January 2019
[21] Ibid.

be flexible enough to adapt to changes in data center technology. Data center designers and operators need to take climate change and its effects into account through the asset creation process:

Flooding can be catastrophic for a data center. Planners are increasingly considering the potential for flood events outside historic norms (Houston has already seen three "500-year" flooding events this decade[22]), and the choice of a data center site must consider the likelihood of worse flooding to come. An increase in flooding incidence not only raises the potential for damage to critical infrastructure, but the likelihood that engineers will not have access to a data center at the most critical moments. Cross referencing sites with screening services like Four Twenty Seven[23] can identify areas that will be prone to future floods.

The increase in flooding events comes against a backdrop of gradual **sea level rise**. A recent report[24] estimated that a one-foot rise in sea level by 2030 will affect an estimated 235 data centers and 771 Point-of-Presence (POPs) in the US alone. The threat is not only to the data centers themselves; in coastal communities, the cables and landing stations upon which they rely for connectivity are particularly vulnerable to sea level rise. Forecast sea level rise needs to be considered in both data center site selection and in determining fiber redundancy.

Too little water can also be a problem. Changes in global and regional **drought** patterns will decrease the availability of water in some regions, making some of data center evaporative cooling techniques less cost effective or downright ineffective. More than 80% of California, ground zero for the global tech industry, was classified as experiencing "Extreme" or "Exceptional" drought conditions in the summer of 2015[25]. This puts pressure not only on data center cooling systems but also on the power plants that feed them - water shortages are another reason to consider renewables, as coal plants can use as much as 11,000 gallons of water to produce a MW of electricity vs. less than 500 per MW for both wind and solar PV[26]. One other key concern for data centers in drought-prone areas is aquifer drawdown, which can lead to land subsidence - a major site selection consideration.

Climate change is exacerbating threats that until recently would have been considered marginal. In areas that are prone to storms, even **lightning** can be an

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[22] AP, "Houston-area voters overwhelmingly back flood-control bond", August 2018

[23] http://427mt.com/

[24] Durairajan, Ramakrishnan, Carol Barford & Paul Barford (2018) "Lights Out: Climate Change Risk to Internet Infrastructure," ANRW ' 18

[25] Friedman, Dov and Tynan DeBold, "California's Long Challenge with Drought," Wall Street Journal, Jan 26 2016

[26] Luciani Castillo, Walter Gutierrez, Jay Gore, "Renewable Energy Saves Water and Creates Jobs," Scientific American (August 2018)

issue for new data infrastructure. Data suggest that a one degree rise in global air temperature would drive a 12% rise in lightning strikes, or an expected ~50% increase over the course of this century.[27] This means more disruption to the grids on which data centers rely.

More droughts and more lightning will inevitably lead to more **wildfires**, and areas like Northern California are increasingly vulnerable to disruption from fires that not only damage or destroy data center infrastructure but potentially cut fiber networks and restrict the ability of data center staff to respond to outages. The likelihood of more wildfires is a threat that should be considered when selecting a site.

Anticipating climate change-related threats is critical to data center planning – these are expensive, mission-critical assets, and the wrong location or design can cut their useful lives short when the environment around them changes.

AVAIO works with third party consultants to assess climate risk for our projects, and incorporates those risks – and their potential mitigants - into our due diligence, design, construction and operations processes. We also look for opportunities to mitigate the effects of climate stress in sectors like water management, energy efficiency, renewables, etc

Measurement – Setting Standards

To give developers some guidance, new standards are being created to quantify and certify data center sustainability. In the US the most widely used is the Green Building Council's "Leadership in Energy and Environmental Design" (LEED) green data center certification and rating system. Under LEED v4.1, data centers have their own dedicated project category and are eligible for certification as silver, gold, or platinum level facilities, based on measurements of environmentally responsible construction and efficient use of resources. Typical LEED-certified data centers use advanced cooling systems, cooling and power efficiency enhancements, clean energy backup power systems, "green" construction methods and, of course, renewable energy for power.

Data centers can also be certified under Energy Star, an EPA and Department of Energy joint initiative. A project's Energy Star score "provides a fair assessment of the energy performance of a property relative to its peers, taking into account the climate, weather, and business activities

[27] David Romps et al., "Projected increase in lightning strikes in the United States due to global warming," Science Magazine, Vol. 346, Issue 6211, (November 14, 2014), 851-854.
[28] "Apple Environmental Responsibility Report: 2019 Progress Report, Covering Fiscal Year 2018," Apple Inc., April 2019

at the property."[29] Only data centers within the top 25% most energy efficient receive Energy Star certification, and they need to maintain that performance every year to keep their status.

Globally, the UpTime Institute's Tier Standards & Certifications for Data Center Design, Construction, and Operational Sustainability are considered the premier standard for data center reliability and performance. The International Organization for Standardization (ISO), an independent, non-governmental international organization, issues the 50001-Energy Management System Certification to support effective energy management programs. TIA-942, ASHRAE, The Green Grid, Infrastructure Masons and other industry groups have also issued standards and guidelines for the design, construction and operation of data centers.

On top of these efficiency and best practices certifications, many of the groups that issue Environmental, Social and Governance (ESG) standards have data center-specific sustainability metrics. The Sustainability Accounting Standards Board's (SASB) Telecommunication Services Standards include key metrics to gauge a facility's sustainability, as does the United Nations' Principles for Responsible Investment (PRI). ESG targets and metrics for their data centers are a key aspect of tech companies' reporting to the Task Force for Climate-Related Financial Disclosure (TCFD), which allows stakeholders in companies to track performance in sustainability.

GRESB, an organization that sets benchmarks for real asset ESG performance, includes data centers in its Telecommunications benchmarking checklists. In Europe, standards are set by the European Union Code of Conduct on Data Centre Energy Efficiency, a voluntary code of conduct that provides energy-efficiency best practices, minimum procurement standards, and methods to track and report power consumption and emissions.

AVAIO is a signatory to the UN's PRI initiatives and to the TCFD, and an active participant in the SASB and GRESB processes – including an AVAIO seat on the GRESB Infrastructure Board.

Conclusion – Threats, but Opportunities as Well

Dealing with the threats from climate change calls for creativity and adaptability from the data center industry. But it also creates opportunities - beyond the green data center itself, innovation and capital are going to be required for new infrastructure to support a sustainable digital economy, including improved water/wastewater handling, data center-driven district heating/cooling systems and resilient and redundant fiber networks and data cables – not to mention the renewable energy projects that will power the whole sector. Beyond infrastructure, the move towards sustainable data centers will drive advances in artificial intelligence, cooling systems, new pump technologies, monitoring software and green design.

[29] Energy Star, "ENERGY STAR Score for Data Center Estimates (U.S. and Canada)," Aug 2018
[30] "2200 Busse Road," *Digital Realty,* https://www.digitalrealty.com/data-centers/chicago/2200-busse-rd-elk-grove-village-il.

The profound changes to civilization brought on by both the digital revolution and climate change require digital infrastructure to adapt, and developers need to be smart and creative in their site selection, design, construction and operations. Data center infrastructure should be at the bleeding edge of clean, sustainable technology, driving advances that will create new opportunities that directly benefit societies.