ENVIRONMENTAL SUSTAINABILITY ON THE FAR EDGE

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EXECUTIVE SUMMARY

In 2022, the world's population stands at about 7.7 billion people, with the UN predicting it will reach 10.1 billion by the year 2100. The demand for energy in the form of electricity is expected to grow nearly 50% globally by 2050, according to the U.S. Energy Information Administration (EIA). To meet the growing global population's need for transportation, communication, clean air, and clean water, international communities and utilities are rapidly converting energy production from fossil fuels to renewable sources such as wind, solar, and hydro. At the same time, vehicles, buildings, appliances, and other traditional fuel-consuming applications are being electrified. As major consumers of electrical power, the data center and telecommunications industries are helping to lead the efforts towards clean energy adoption and sustainability.

The October 2021 TIA white paper entitled "Where's the Edge?" created a framework of edge computing implementations as envisioned by the telecommunications industry. In this paper, we now explore how the Information Technology (IT) sector can overcome the challenges of powering new infrastructure in disparate locations, while also meeting global and corporate decarbonization goals.

THE FAR EDGE MODEL

While the basic concept of the edge is "IT everywhere," it still can be reasonably categorized into common areas of deployment. In the previous paper, we introduced a holistic Far Edge model based on proximity, function, and application use rather than physical location using five key defining characteristics. This model identifies network performance, acknowledges IT proximity, and standardizes the language for the Inner, Outer, and Far Edge layers of the edge ecosystem.

The Far Edge model recognizes that as we move further away from a centralized data center model, we also move away from critical IT functional aspects of the traditional computer model that we commonly take for granted. These functional aspects can range from data management across the WAN and application mobility, to data distribution across autonomous networks. However, there are several new and even unknown conditions that impact accessing, analyzing, and managing data on the edge as we migrate away from the core data center.

As shown in Figure 1, as we move further away from the Inner Edge and traditional TIA-942 data centers, the potential power footprint shrinks and becomes decentralized. Finding sustainable and resilient localized power sources at the Far Edge can be challenging. The power efficiency of both IT and facility services becomes a key performance factor—the less energy you need, the easier and less expensive it is to provide power.

The decentralized edge delivers the benefits of low latency and higher application performance, while utilizing common cloud services to manage secondary data sets and monitor the primary real-time application data localized to the end user. However, as this decentralized "Converged Edge" evolves to move towards the Far Edge, decoupling of the core computing components and maintaining sustainable, adequate, and resilient power to support individual edge devices becomes increasingly challenging. Multiple factors impact the edge, from traditional power design to the emergence of sustainable technologies.

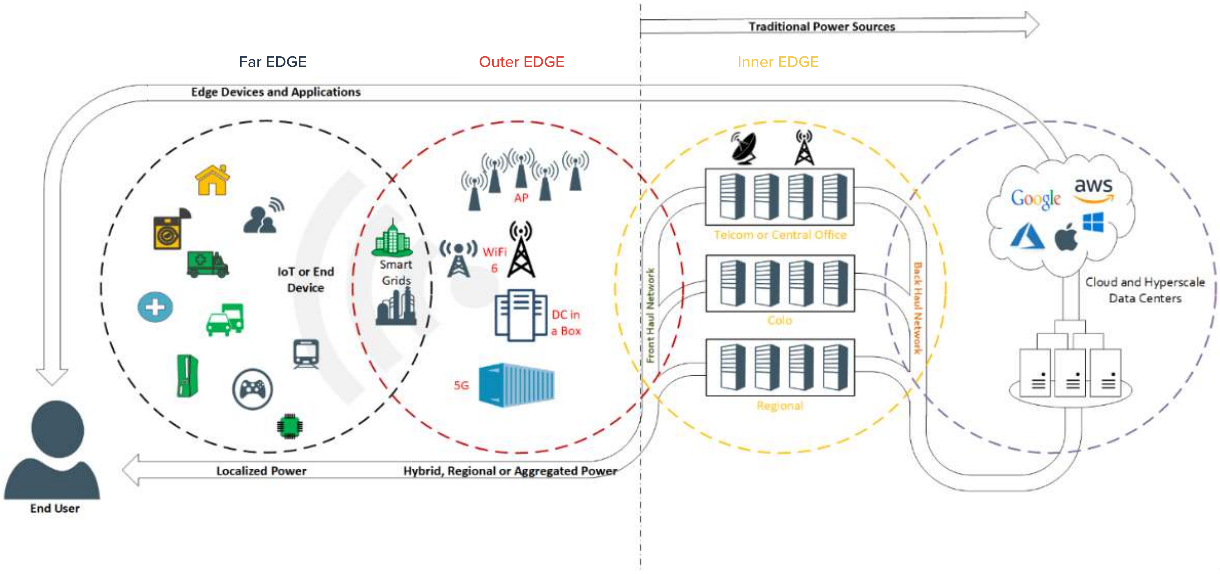

Figure 1: Power Distribution across the Edge

REDUCING CARBON EMISSIONS AT THE EDGE

Climate change affects everyone, and the data center industry is a key player in achieving COP26 (26th session of the Conference of the Parties) and future United Nations Climate Change conference goals. Most data centers have an aggressive target to reach either 100% renewable energy or achieve net zero for carbon emissions from 2025 to 2040, including leading hyperscale and multi-tenant data centers like Google, Amazon, Microsoft, Alibaba, NTT, Iron Mountain, Cyrus One, Vantage, and others. Various industry alliances and governments are setting carbon emission reduction targets for their various industries, such as the Climate Neutral Data Centre Pact and the European Commission's Code of Conduct for Energy Efficiency in Data Centres. Sustainability is also a core initiative of the Infrastructure Masons (iMason) Climate Accord comprised of companies committed to reducing carbon in digital infrastructure by adopting newer technologies that enable a more sustainable data center.

The Green Grid has introduced several key efficiency metrics available for data centers. Defined as the total energy used by a data center against the energy employed only by its IT equipment, Power Usage Efficiency (PUE) was introduced in 2007 and quickly became the key metric for measuring system performance and efficiency. It was discovered early on that PUE alone cannot capture a data center's true overall energy efficiency. As a result, the Green Grid has augmented PUE with Carbon Usage Efficiency (CUE), which is defined as the relation between the carbon emissions produced by the data center and the energy consumption of IT equipment, and Water Usage Efficiency (WUE), which is defined as the ratio between water usage in a data center and the energy consumption of the IT equipment.

PUE, CUE, and WUE metrics are now maintained by the International Standards Organization (ISO)/International Electrotechnical Commission (IEC) in the ISO/IEC 30134 series of standards. These standards define key performance indicators (KPIs) for these metrics with the goal of achieving the most efficient use of the least number of resources possible, including energy reuse and renewable energy sources.

$$\text{PUE} = \frac{\text{Total Data Center Energy}}{\text{IT Equipment Energy}} = \frac{\text{IT Eq. Energy + Non-IT Eq. Energy}}{\text{IT Equipment Energy}} = 1 + \frac{\text{Non-IT Equipment Energy}}{\text{IT Equipment Energy}}$$

$$\text{CUE} = \left(\frac{\text{kgCO}_2}{\text{kWh}}\right) = \frac{\text{Data Center Power Production Total CO}_2\text{ Emissions}}{\text{IT Equipment Energy Consumed}} = \text{CEF x PUE}$$

$$\text{CUE} = \left(\frac{1}{\text{kWh}}\right) = \frac{\text{Data Center Water Consumption}}{\text{IT Equipment Energy}}$$

Figure 2: PUE, CUE, and WUE metrics

The following technologies and practices can help improve PUE, CUE, and WUE metrics at the edge:

- **Sensors:** Deploying detailed monitoring of temperature, humidity, air quality, server usage, and electricity consumption
- **Digital Twins:** Using Data Center Infrastructure Management (DCIM) for in-depth analysis of the data center data to autonomously meet the customer requirements at the lowest PUE and lowest CUE
- **Cooling Innovation:** Identifying opportunities on a site-by-site basis to use outside air and/or liquid to cool the data center as much as possible, noting that liquid cooling is significantly more efficient than air
- **Optimization:** Improving server utilization by running them at peak performance and ensuring idle servers remain in a power-saving state
- **Proactive:** Looking for new innovative ways to reuse energy or resources wherever possible

The increasing number of data centers and new edge applications requiring high computing capacity will further increase power used by data centers, demanding more efficient and effective cooling systems to improve the efficiency of the servers. Although total power used by data centers is expected to grow, fortunately the supply of renewable energy is expected to grow even faster. In 2021, a record amount of more than 290 Gigawatts of renewable power capacity was added globally, and renewable energy is the fastest-growing energy source in the United States, increasing 42% from 2010 to 2020.

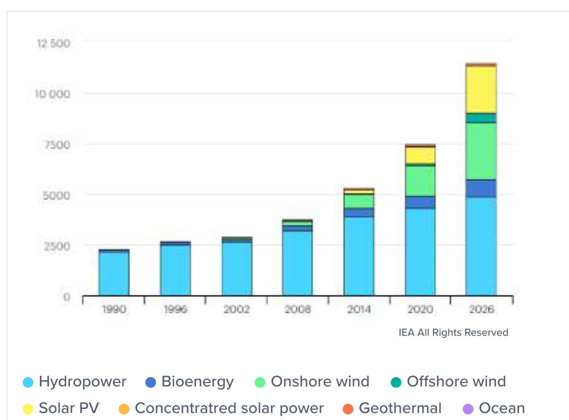

Figure 3: Renewable Electricity Generation by Technology 1990-2026

REDUCING POWER CONSUMPTION AT THE EDGE

The needs of Far Edge infrastructure will vary greatly depending on the physical location and environment in which it is deployed. It is this variability that will often necessitate custom-designed solutions tailored to the respective location versus traditional centralized data center solutions.

The power consumption of a Far Edge device typically falls in the range of 1 to 1000 Watts. Edge infrastructure situated in urban environments is typically going to be supported by the local energy utility. Most utilities are working towards 100% renewable energy production, having shifted away from coal and natural gas towards solar and wind as their primary energy sources. For urban edge, whether Inner, Outer, or Far Edge, the infrastructure operator can use Power Purchase Agreements (PPA) with the local utility to ensure sourcing of low carbon and carbon-free energy. In the U.S. and around the globe, major wireless telecom providers are choosing this approach wherever possible.

For deployments outside of urban areas, it is increasingly attractive to generate power locally through small photovoltaic (solar) arrays or other renewable energy sources rather than trying to extend adequate utility power to the location. Depending on the power density and overall power consumption, additional generating capacity may need to be factored in for the cooling needs of Far Edge infrastructure

Power consumption can be mitigated or reduced through appropriately selected componentry designed to withstand a wider operating temperature range, thereby allowing the Far Edge facility to partly rely on free-air cooling in lieu of air conditioners, chillers, and other methods found in centralized data center locations. Choosing equipment capable of operating in in a -40˚C to +65˚C temperature range can maximize operation time that does not require supplemental cooling. Fanless equipment that relies only on the use of ambient air also helps to address the PUE, CUE, and WUE metrics of the individual site and the overall network of Far Edge locations.

Industrial class embedded computers, solid state drives, and low-power optical networking hardware enable reliable high throughput communications and computation to be delivered from Far Edge infrastructure. Where the expected workloads exceed the capacity of industrialized class equipment, higher power consumption equipment may be necessary. In this case, liquid cooling may be explored as a cost-efficient and environmentally friendly means of lowering the power budget and operational costs, while optimizing the efficiency metrics of the site. Avoiding the use of compressor-based HVAC systems is a key design objective with most telecom carriers and edge computing platforms as their use causes a penalty relative to liquid-based and free-air cooling alternatives.

CONCLUSION

Assessing the sustainability and carbon usage of most goods and services, along with that of compute and wireless infrastructure, will gain importance in the years leading up to 2030 and the Sustainable Development Goals promoted through the UN. Companies responsible for deploying IT and telecommunications gear will be asked to improve efficiencies in all phases of the network - equipment production, installation, operation, and reuse/recycling end-of-life systems.

To keep pace with sustainability the IT equipment utilized must exceed today's environmental standards, such as TIA-942, ISO 14064 and ISO 30134, from usage to disposal of such equipment. The adoption of new design methodologies and cooling approaches, coupled with the use of low-power consumption devices, will enable remote installations to operate 'off-grid' through local power generation much of the time, helping the telecommunications industry to lead the way in achieving environmental sustainability on the Far Edge.

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