# How Digital Technologies Are the Key to Reducing Emissions

**Special Report**

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As Research Director of the Internet of Things practice for 451 Research, a part of S&P Global Market Intelligence, Christian Renaud covers the ongoing virtualization and digitization of the physical world around us.

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# Executive Summary

- Digital technologies are some of the primary tools for addressing many of the challenges that society faces in combating climate change.
- In the short term, digital technologies enable organizations to reduce energy and emissions by leveraging pervasive sensors, connectivity innovations such as 5G and artificial intelligence. In the longer term, these technologies will fundamentally change how organizations deliver value to their clients in a low-carbon future.
- This combination of sensors, connectivity and artificial intelligence is being applied today in every industry, specifically in the four primary industries discussed in this report: electricity, buildings, datacenters and transportation.
- Advances in one industry will help others. The proliferation of smart grid technologies, for example, will make it easier to accommodate more electric vehicles and charging stations. These in turn will generate demand for efficient datacenters to process the data from the increasingly intelligent power grids and cars.

# Digital's Role in Sustainability

Climate change can no longer be denied. The Intergovernmental Panel on Climate Change has estimated that human activities have caused approximately 1.0°C of global warming above pre-industrial levels, and that number is likely to reach 1.5°C between 2030 and 2052 if emissions continue to increase at the current rate. To date, 59 nations have called for a 50% reduction in worldwide emissions by 2030 and achieving near-zero emissions by 2050. Achieving net zero emissions will require, among other tasks, replacing oil with electricity in transportation and replacing fossil fuel power plants with renewables. The US Energy Information Administration estimates that, as a result, worldwide electricity demand will more than double to 45 trillion kilowatt hours by 2050.

Digital technology will play a fundamental role in this shift. Smart grid technologies effectively involve leveraging sensors, analytics and high-speed connectivity to fine-tune supply and demand for electricity in real time. Not only will these technologies reduce the 'intermittency' problem of solar and wind, but they can be deployed to unobtrusively reduce waste for businesses and consumers. The result, potentially, is a cleaner grid, a better customer experience and lower costs.

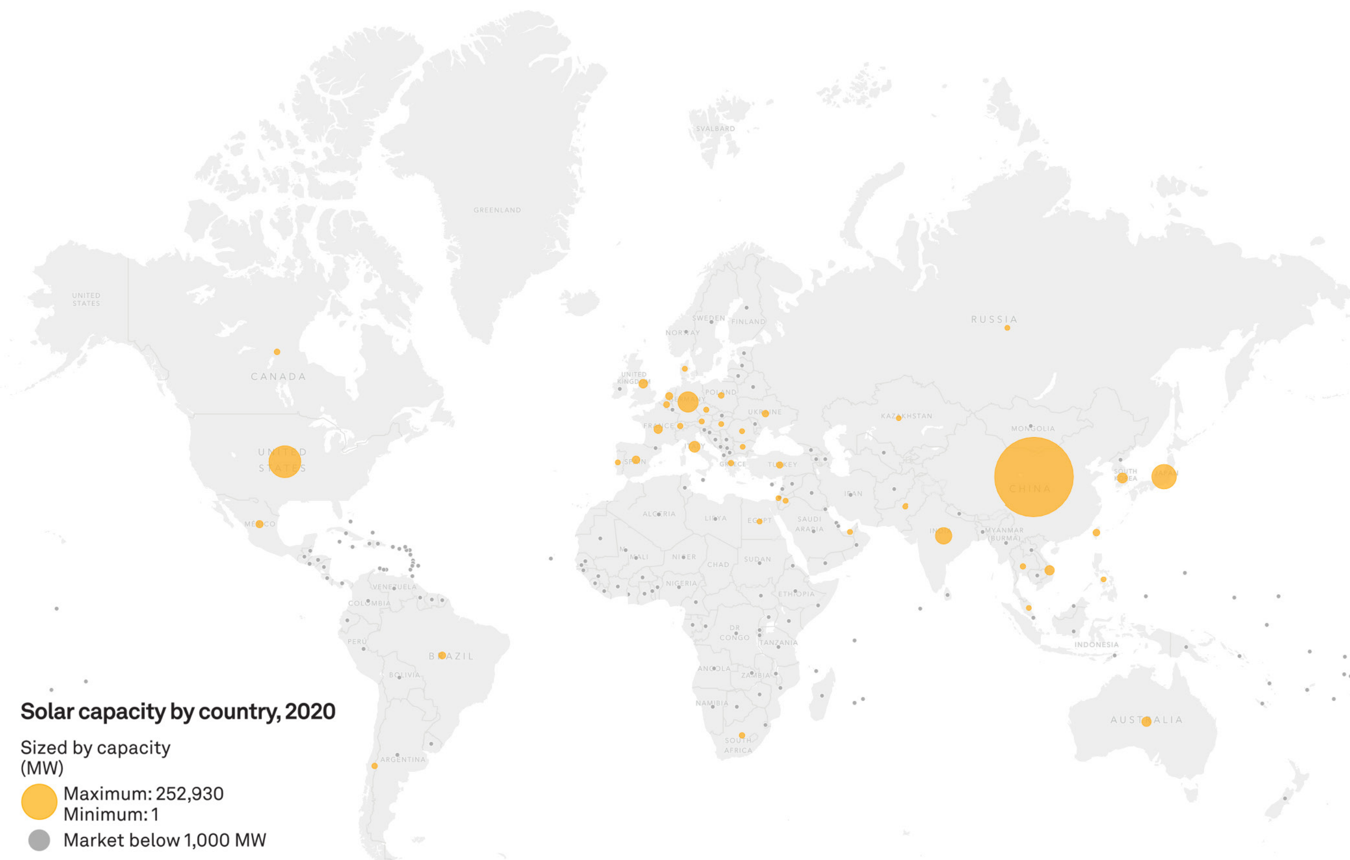
Hardware and software will also play a leading role in reducing the energy consumption and improving the performance of household appliances, cars, manufacturing equipment and other devices. Again, better experiences – the silent acceleration of electric vehicles (EVs), predictive maintenance services from OEMs, etc. – will be delivered hand in hand with economic gains. The technology industry, however, will have to continually raise the bar in terms of performance per watt to ensure that the power consumed by these new cloud and edge services does not erode the gains.

## Electricity: A Complete Makeover

The energy sector is the dominant emitter of greenhouse gases, with IEA estimating that the sector produces 76% of all emissions globally and will generate 33 billion tons of CO2 in 2021.

Low-carbon-emitting renewable sources now represent 9% of electricity-generating capacity globally. Global wind capacity has grown from 175 gigawatts (GW) in 2010 to almost 740GW in 2020, while solar has gone from 40GW to over 730GW in the same period, according to S&P Global Platts Analytics. Even with this tremendous growth in renewables, coal remains the dominant source of global energy generation: the IEA estimates that coal accounts for 27% of all energy used worldwide and makes up 38% of electricity generation. Critical technologies such as inverters and a broad variety of sensors will ensure that these generating assets are kept operational and at peak efficiency.

## Figure 1: Solar Eclipsing Wind

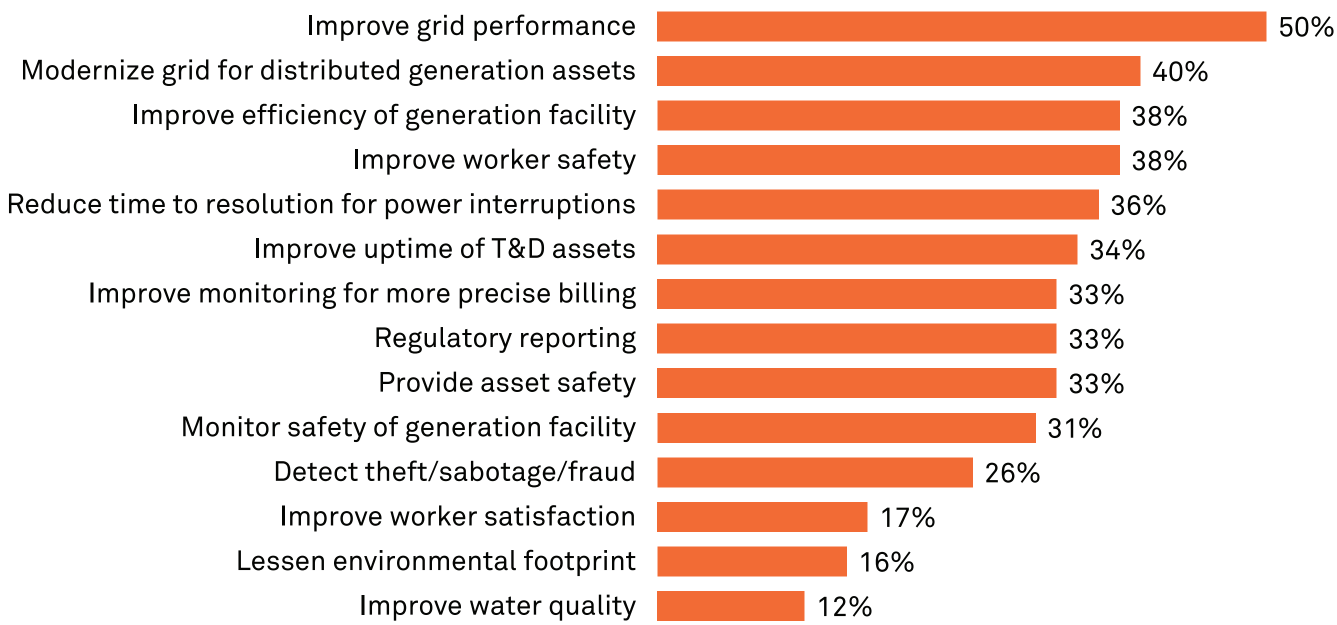



Source: S&P Platts Atlas of Energy Transition

Digital technologies, paired with the broad deployment of renewables and existing energy-efficient technologies, is the quickest path to cut carbon emissions. The Intergovernmental Panel on Climate Change has stated that the widespread adoption of electrification and renewable energy sources, as well as deployment of existing efficient technologies at scale, could reduce approximately 60% of global emissions.

According to 451 Research's Voice of the Enterprise: Internet of Things, The OT Perspective 2020 survey, improving grid performance, accommodating for distributed energy resources (DERs) such as wind and solar-photovoltaic, and improving existing power-generation facilities such as coal-fired plants are the top three drivers of IoT adoption in the utilities sector.

**Figure 2: IoT Deployment Drivers – Utilities**




Q: Which of the following goals are drivers of your organization's deployment of IoT? Please select all that apply.
Base: Utilities respondents (n=58)
Source: 451 Research's Voice of the Enterprise: Internet of Things, The OT Perspective, Use Cases and Outcomes 2020

## Digital Technologies' Role in DERs and Grid Performance

The transmission and distribution networks are a primary target for digital improvements as existing infrastructure is updated to support distributed energy resources, demand response, load shedding and shaping, and micro-gridding. Renewables, efficiency and smart grid control are interrelated: by being able to fine-tune consumer demand – an extremely difficult task with traditional grids – utilities can modulate the impact of renewable intermittency while maximizing their output, achieving a flywheel effect that accelerates growth.

Optimizing energy production and matching demand and supply increasingly becomes a data-driven process. At any given time, utilities need to know how much energy is produced by residents in their service area and how much energy they will consume. While the first generation of smart meters gave utilities the ability to occasionally check the meter remotely, the latest generation of smart meters provides real-time insights. This real-time insight helps utilities balance the grid, but it also offers the opportunity for more precise billing as consumers pay current prices instead of wholesale prices.

The Internet of Things is also transforming the transmission and distribution infrastructure. Sensors allow utilities to monitor substations down to the fuse level and across the many miles of transmission lines to detect outages and redirect power supply to avoid wildfires or mitigate blackouts. Electric utilities such as CenterPoint Energy in Texas have leveraged distributed analytics for predictive maintenance and to reduce the impact of catastrophic grid events from adverse weather such as hurricanes. Larger wind turbines, meanwhile, can send as much as one petabyte of data per year, which can be used to analyze the wind conditions and adjust the blades to optimize power generation. 5G will further improve the speed and range of coverage required for connecting the network of sensors and actuators in the 'sentient grid' under development.

Digital twin technology is gaining importance for energy companies in monitoring the real-time status of the grid. Digital twins can help in short- and long-term planning and can be used for planning EV charging demand, as well as to map out where to build high-speed chargers. Digital twins can also be used to simulate the addition of virtual power plants from a combination of renewable sources to deliver more flexible peak load electricity. Beyond monitoring the real-time status of the grid, utilities increasingly add artificial intelligence (AI) and machine learning (ML) to their analytics to augment historical and real-time performance data with weather forecasting to predict demand and supply to avoid energy waste and load discharge.

### Digital's Role in Improving Brownfield Generation

The S&P Global Environmental Project Database estimates that over 100 coal plants totaling 130GW (or more than half of the US coal-fired fleet) have undergone or are planning to undergo environmental retrofits in some form to reduce emissions before their end of life. These retrofits frequently incorporate sensors and analytics to optimize conversion efficiency. On average, coal-fired power plants have a conversion efficiency of approximately 33%, but with the help of emissions sensors and continual condition monitoring, this could improve to as much as 49%. The coal sector contributed 10 gigatons (Gt) of CO2 in 2018, according to the International Energy Agency, so this would result in a possible reduction of as much as 1.6Gt of CO2, or nearly 5% of all energy-related emissions.

## Buildings: Efficiency Through Intelligence

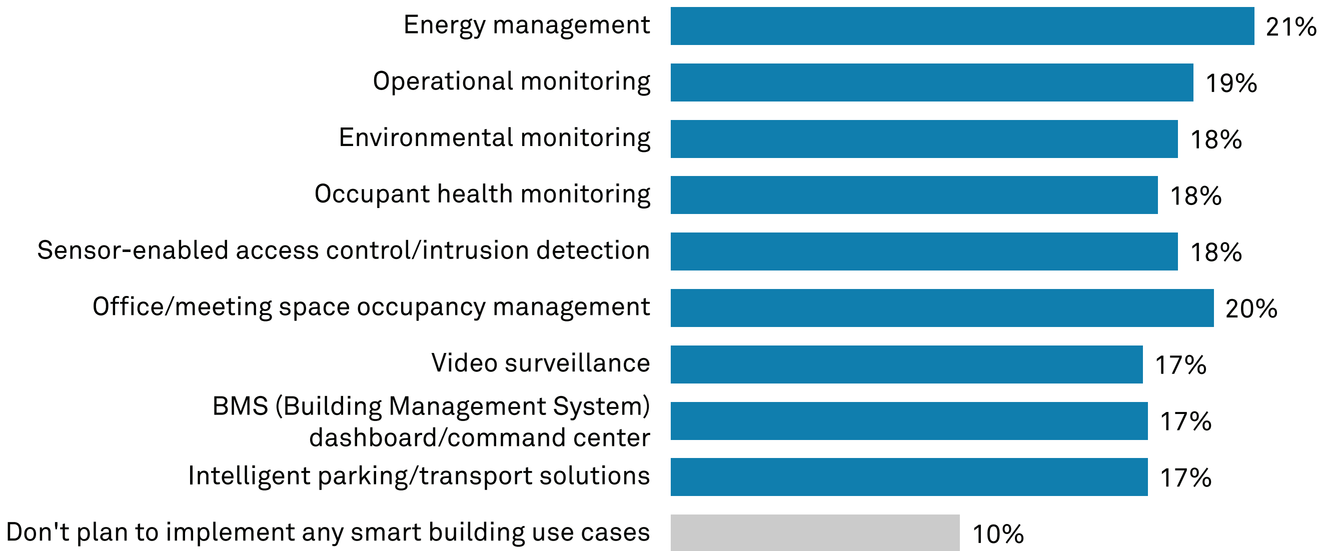
Commercial and residential buildings are responsible for over one-third of all global CO2 emissions, according to the IEA. Within the sector, 64% of emissions come from residential buildings and 27% come from commercial buildings, with public sector emissions accounting for the remainder. Roughly 30% of energy consumed by commercial buildings is also wasted due to poor insulation and unnecessary heating, cooling and lighting, according to the EPA. Global building stock is expected to double by 2050, according to the Programme for Energy Efficiency in Buildings. Achieving net zero goals will require updating building codes and technologies for new construction. Efficiency gains from existing retrofits will also need to increase by at least 3% per year, double the current rate, according to the Global Alliance for Building and Construction.

Both existing and new buildings represent an attractive opportunity to improve emissions with digital technologies. Existing trends toward open seating plans and zone heating and cooling have contributed to improvements in efficiency, with floor space increasing 21% over the last decade while CO2 emissions and energy consumption have only risen by 9% in the same period.

Digital technology will play a considerable role in making fixtures such as heating and cooling systems and lights inherently more energy-efficient, as well as tying those systems together in AI-enhanced IoT networks to unobtrusively micromanage power. The global stock of air conditioners in buildings, for instance, is expected to grow to 5.6 billion by 2050, up from 1.6 billion today, according to IEA estimates. Unchecked, space cooling could consume as much power in 2050 as all of the power consumed by China and India today. But with digital technologies and new policies, average efficiency can be doubled, lowering the forecast for energy consumption by 45%.

It's not surprising, then, that respondents to 451 Research surveys of professionals responsible for building technology cited energy management and operational monitoring as top planned digital projects.

**Figure 3: Smart Building Use Cases in Plan**




Q: Which of the following IoT smart building use cases that your organization does not deploy today does it plan to implement within the next two years? Please select all that apply.

Base: All respondent (n=545)

Source: 451 Research's Voice of the Enterprise: Internet of Things, The OT Perspective, Use Cases and Outcomes 2020

New construction can leverage 'building energy modeling' tools to design structures for maximum efficiency, simulating building orientation, sun shading, seating layouts and density of workers to minimize energy consumption while enhancing worker experience and comfort. The infrastructure to monitor location and density of individuals, such as motion detectors and video analytics, can also be leveraged to enable/disable lighting and HVAC systems to conserve energy, and information can be shared with premises security to ensure worker access only to authorized locations is enforced.

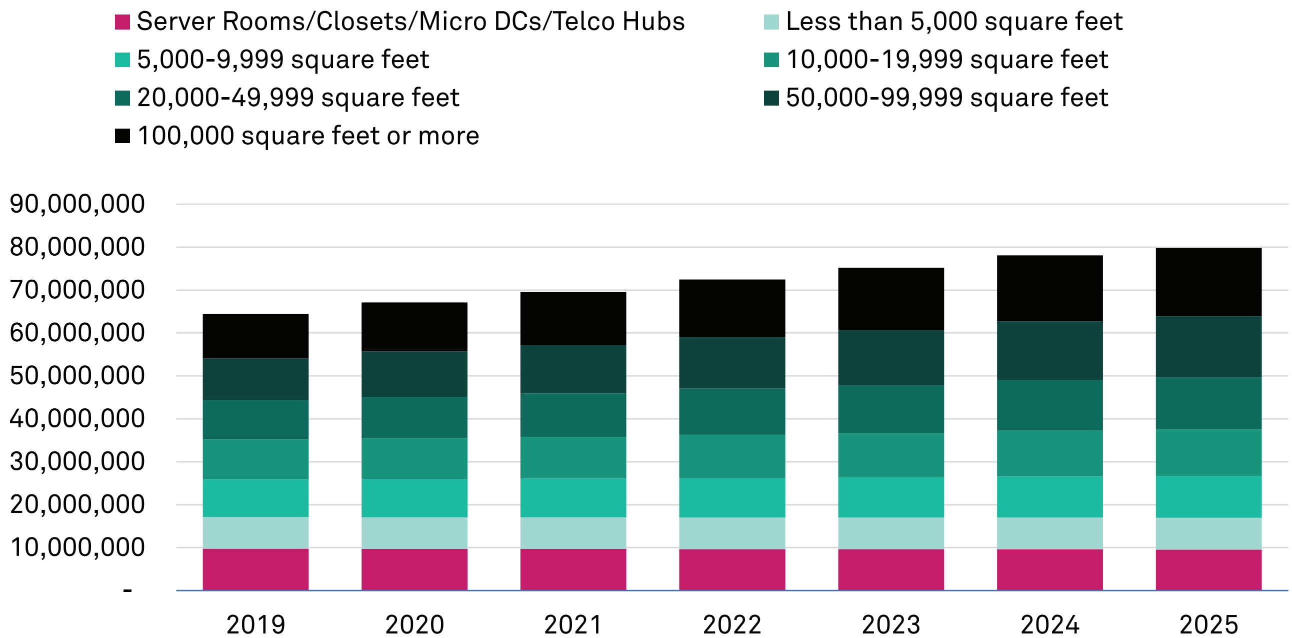
## Datacenters: Growth (in Workloads) Without Growth (in Power)

The 451 Research Datacenter Market Monitor estimates that there are nearly 230,000 datacenters globally – not including smaller (edge) server rooms and closets – containing over 14 million server racks. This includes private datacenters, multi-tenant datacenters (MTDCs), and cloud and service provider datacenters. Demand for capacity, and the resultant traffic, is growing with hyperscale cloud providers commissioning new cloud datacenters along with additional edge capacity. MTDC capacity alone is projected to grow at a compound annual growth rate of 8% from 2020-2026.

We also anticipate a surge in edge datacenters. These datacenters, from closets and cages to multi-access edge computing locations at mobile network operator locations, will number in the tens of millions and are growing more rapidly than their larger, centralized siblings. Edge computing will not replace cloud computing; however, it will consolidate currently disparate workloads and applications scattered throughout organizations onto more optimized hardware platforms on-premises or nearby.

Interestingly, despite all this growth, power consumption from datacenters hasn't grown as a percentage, relative to all other industries. The exact figure can be a bit hard to get at, but the general assumption is that datacenter power consumption represents 1-2% of global electricity usage. While this is still a staggering amount, it has remained steady thanks to efficiencies being found – from the hardware sitting on the datacenter floor to the operation of the building itself. There is still much work to be done, however.

**Figure 4: Total Datacenter Utilized Power (kW) by Datacenter Size**




Source: 451 Research's Datacenter Market Monitor

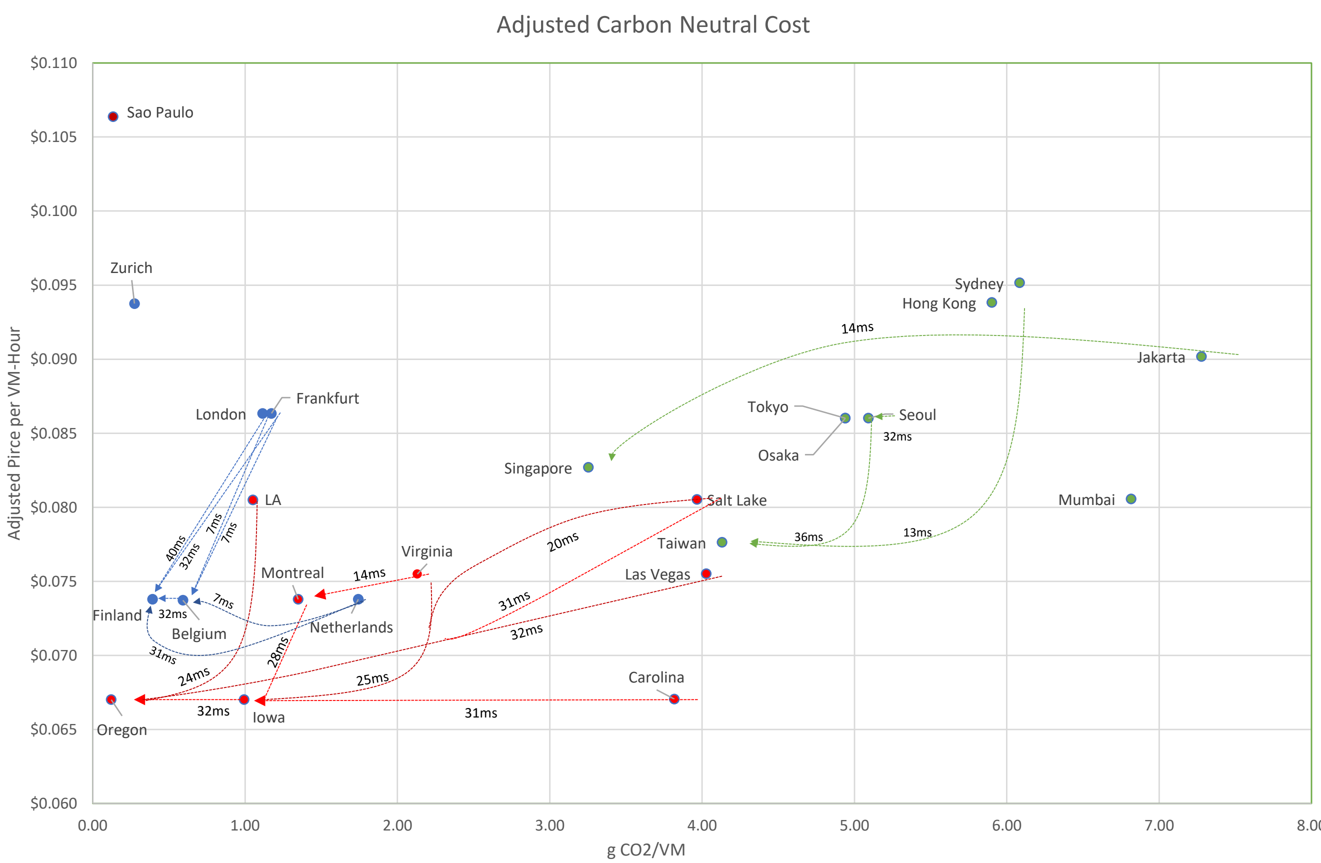
The most efficient datacenters are already approaching a power usage effectiveness (PUE) of 1.1, meaning that a very low percentage of the building's overall power usage is beyond servicing the load for things like cooling. Most organizations aren't there yet, though, and in some environments (the tropics, for example), it's nearly impossible with current technology to get PUE scores that low. Still, what is inside the datacenter can make a big difference, ultimately conserving more energy.

The enterprise segment and cloud providers alike will need to increasingly experiment with computing architectures to keep power flat or lower it. For example, servers account for much of the power demand on the datacenter floor, especially now that spinning disks are slowly going away. SmartNICs, digital processing units, new GPUs and CPUs, flash memory arrays and other technologies can effectively perform more work within the same power envelope, increasing performance per watt. The enterprise segment, however, has traditionally been somewhat slow to replace older servers. This is one area where the cloud providers excel – it ultimately behooves them to be able to do more work for less power because the bulk of their month-to-month expenditures for infrastructure is on power. So, by either moving workloads to the cloud or by moving workloads to more efficient processor times, companies can reduce the overall energy usage of their infrastructure.

Over the last decade, datacenter owners have been taking steps to locate new datacenter sites in areas with green and renewable energy grids or near renewable generation facilities. Where this wasn't possible, owners would buy renewable energy certificates to at least support the growth of green energy overall. The current trend of the largest providers is to take part in power purchase agreements, bringing new renewable energy online in the markets where they operate, so they are suppling renewable energy to the grids they are pulling from. As a result, cloud providers such as Google are now offering services to shift client workloads from datacenters that have higher emissions (i.e., the incoming electricity is not from renewable or other green sources) to those datacenters that are powered by renewables, but with a latency trade-off.

For example, in Figure 5 below, carbon per VM is plotted against the cost of an e2-standard-2 instance in that region. Datacenters to the left and below represent those with both lower costs and reduced bandwidth. The arrows represent migration paths from datacenters where costs and carbon are reduced while latency is increased by a maximum of 40ms. Each arrow shows the latency 'sacrifice' that takes place due to the migration in return for lower carbon and costs. Latencies are extracted from Google's own data studio website.

**Figure 5: Costs and Carbon Associated with Google Datacenters, with Lines Indicating Potential Cost- and Carbon-Saving Migration Paths and Latency Impact**




Source: 451 Research

451 Research expects enterprises and cloud hosting companies will continue to seek to extract higher utilization from their existing assets and make workloads more efficient via technologies like virtualization and containerization. We also see from our Voice of the Enterprise surveys that companies are already moving workloads to reduce carbon emissions. We expect this trend to continue as well.

## Transportation: The Green and Connected Revolution

The US Environmental Protection Agency (EPA) estimates that 29% of 2019 US greenhouse gas emissions were from passenger automobiles and commercial transportation such as rail, trucking, maritime vessels and aircraft. This also encompasses transportation-supporting structures such as airports, rail stations and ports.

One key technology already enjoying rapid growth is the battery electric vehicle (BEV) with zero tailpipe emissions. BEVs are replacing cars with internal combustion engines, which emit an average of 4.6 metric tons of CO2 per year per car.

Forty million electric passenger vehicles are forecast to be sold by 2025, driven in large part by government incentives in the US, China and the European Union. These vehicles combine modern battery technology, onboard connectivity and robust computing to provide competitive range and superior performance and economics to internal combustion engine cars. Automakers such as Toyota, General Motors and Groupe PSA have announced extensive plans to electrify their vehicle offerings by 2025-2030. To reduce costs and improve performance, car manufacturers will continually enhance the intelligence of their batteries with software and hardware to fine-tune charging and discharging, economically extend driving ranges, and potentially extend the lifetime of their products.

S&P Global Platts anticipates that 50% of new passenger vehicles will be battery electric by 2050, which holds the potential to reduce global CO2 emissions from the transportation sector by greater than five billion tons annually.

These new electric vehicles will require a global increase of 2,090 terawatt-hours (tWh) of power per year for charging alone by 2040, according to S&P Global Platts, equivalent to roughly half of the current US generating capacity. This will create a demand for rapid buildout of charging stations and supporting transmission and distribution networks. We are already seeing accelerated projects from systems operators to leverage local distributed generating sources, such as renewables, to charge EVs during peak renewable times (daylight for solar) while the vehicles may be parked in a work parking lot. Another example is to potentially tap into these same EV batteries with inverters as distributed storage during peak load times, such as during heat waves when homeowners want to run air conditioning units. This puts a strain on generating capacity and frequently demands that additional capacity be brought online in the form of high-emitting coal plants.

Passenger vehicles are also undergoing a major shift from distributed electronic control units dedicated to controlling a limited number of functions to more capable domain control units running more advanced CPUs and GPUs for centralizing several applications, as well as supporting advanced capabilities within advanced driver assistance systems (ADAS). ADAS is a broad area that includes passive functions such as backup object detection as well as active features such as lane keeping and adaptive cruise control. ADAS will continue to grow in sophistication toward Level 5 ‘full autonomy,’ where all driving functions are performed independently of any human passengers. The 451 Research Internet of Things Market Monitor identifies the ‘data exhaust’ from these connected and intelligent vehicles to be the largest and among the fastest-growing sources of compute and data of all sectors and expects it will contribute to faster-than-anticipated growth in both edge computing infrastructure and cloud datacenters. In short, more onboard compute will heighten the need for greater onboard compute efficiency, as well as fuel demand for efficient cloud and edge services.

# Conclusion

Several concurrent transformations are occurring in the energy sector: optimization of electricity generation and delivery, making buildings increasingly intelligent and energy-efficient, scaling compute capacity in datacenters while striving for the minimal power consumption, and the electrification of the passenger vehicle fleet. These concurrent transformations will generate large gains in reaching net zero emissions as a society and reducing the impact of these industries on climate change threats. However, they will require the aggressive adoption of sensors, connectivity and analytics to identify sources of emissions and to develop plans for mitigation. Sensors, connectivity and analytics will need to be designed into new distributed energy resources, the electric grids that connect them with consumers, the datacenters that digitally enable the analytics to drive insight, and the increasingly autonomous and electrified cars of the future. It will be the combination of all of these efforts and transformations that will ultimately pave the path to net zero emissions.

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