

# ESG and Technology: Impacts and Implications



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How to effectively treat environmental, social and governance issues, collectively known as ‘ESG,’ is shaping up to be one of the most significant agendas of our time. Major commitments are being made in company boardrooms, but the ESG mandate is challenging for many companies to embrace. The role of the technology industry is underexplored, yet it has an oversized potential to influence the mandate. Investors, consumers, technology buyers, end users and suppliers are trying to understand the implications of ESG and what it means for how technology is used. We anticipate the range of discussions around technology and ESG will rapidly become more frequent, specific and strategic. This report frames some of the main issues and addresses the varying levels of maturity of the different ESG dimensions.

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# About the Authors



## **Chris Marsh**

### **Principal Research Analyst, Workforce Productivity & Collaboration**

As Principal Research Analyst, Chris Marsh sets the vision for and manages the Workforce Productivity and Collaboration practice at 451 Research, a part of S&P Global Market Intelligence. The WPC practice focuses on a broad range of enterprise software including technologies supporting workforce planning, project and work management, collaboration, content and innovation management, learning and skilling and content creation. The team also covers the full spectrum of HR technologies from candidate marketing and recruitment through core HR processes and out to new types of employee engagement tool. Marsh also leads the ESG working group within 451 Research which draws together perspectives from across the division's different research practices.



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# Executive Summary

## Introduction

How to effectively treat environmental, social and governance issues, collectively known as 'ESG,' is shaping up to be one of the most significant questions of the decade for businesses and investors. ESG is becoming a major strategic imperative, especially for large and public organizations. In the boardroom, we're seeing companies make long-term commitments to address climate change – the 'E' in ESG. The pandemic and social justice movements cast more of a spotlight on the 'S' in ESG, and as a result we've seen more companies taking action to address social issues like worker safety; diversity, equity and inclusion (DEI) policies; and systemic racism.

In addition to external pressures to address ESG issues, more businesses are also realizing the benefits of embedding ESG criteria in fundamental business practices to reduce their exposure to a range of risks, to improve their baseline performance and to create businesses that will be sustainable over the long term. Some of the biggest investment funds set up with ESG criteria outperformed the broader market early in the coronavirus pandemic. More than half of the ESG-linked funds included in [a new analysis](#) by S&P Global Market Intelligence outperformed the S&P 500 in the first several months of 2021.

But the ESG mandate presents many challenges for companies: The topic is broad and complex. Many competing frameworks and standards exist around the globe. What's more, the rules around ESG are very much in flux as regulators worldwide debate what disclosures are mandatory. This lack of standardization means that available data is often patchwork.

These challenges present an opportunity for the technology industry. All actors – including investors, consumers, technology buyers, and their end users and suppliers – are trying to understand the impacts and implications of ESG and what it means for how technology is used.

For all these reasons, we anticipate the range of discussions around technology and ESG will rapidly become more frequent, specific and strategic. This report is intended to frame some of the main issues and address the varying levels of maturity of the different ESG dimensions.

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## Implications for Consumers

Momentum around ESG has grown as businesses look for ways to mitigate reputational and business risks in the face of growing pressure for more socially conscious practices. These risks have intensified in subsequent years, with wider social changes manifesting in a new consumer ethos. ESG issues are not only becoming more prominent in individual purchase decisions, but the whole value chain from sourcing to product to packaging to reputation is being influenced by growing consumer interest in sustainability, DEI and fair trade.

There is significant risk yet substantial opportunity for brands in the growing focus on ESG issues. One potential upside is that for many businesses, improving their customer experience is among their most important digital transformation priorities. The kinds of things they are focused on – namely operational effectiveness, customer service responsiveness, and data protection and privacy – are becoming more important factors in social and governance measures. If businesses manage to align around both the ESG mandate and their customer experience strategy, they should be able to realize significant synergies and pass the benefits on to consumers.

## Implications for Technology Buyers and IT End Users

For most businesses, however, understanding the implications of technology adoption for ESG strategies is still early days. Only 29% currently have a formal ESG strategy, according to HR leaders surveyed in 451 Research's Voice of the Enterprise (VotE): Workforce Productivity & Collaboration (WPC): Employee Lifecycle & HR 2021 survey. Even among those that do, most are unlikely to be measuring the ROI of their strategies – it's common to see it as an important cost of compliance rather than delivering a business return. The majority of businesses do not apply an ESG lens across their technology investments, and relatively few technology providers strategically market ESG credentials around their products, services and engagement models, although this is beginning to change. Where there is existing commitment on the buy side, it's typically from an ethical procurement perspective – businesses wanting to demonstrate they are working with suppliers that take issues of sustainability seriously.

However, pressure on boardrooms and the c-suite to commit substantially to ESG goals is growing. For example, the US Securities and Exchange Commission (SEC) created the role of senior policy adviser on climate and ESG and beefed up its examinations of whether companies' business continuity and disaster recovery plans are factoring in extreme weather threats. The SEC also launched a review of corporate climate-related financial disclosures and has increasingly signaled that a new regime of corporate disclosures around climate and ESG risks is coming. As Wall Street's top regulator, the SEC plays a critical role in determining which disclosures are mandatory and how companies engage with their shareholders.

One of the questions businesses will be asking themselves is where to start. They are increasingly reliant on their digital infrastructure running their operations and the digital experiences they provide their employees, partners and customers. For large enterprises, this likely amounts to hundreds, if not thousands, of individual technology supplier relationships and a growing number of digitized business processes. This dependence widens the scope of threat vectors and risks to be managed. With new ESG commitments, businesses will need to understand whether their existing risk management and other governance controls will be effective.

At the same time, technologies will underpin new products, processes and practices that will support more data-driven decisions that will help mature ESG commitments. They will also provide the basis for new kinds of relationships with employees and customers through which commitments to good practice can be made more material. Growing expectations to understand the energy efficiency of both hardware and software assets will improve the measurement and reporting of environmental impacts. Many businesses will have learned from their digital transformation strategies how to lower organizational boundaries and drive alignment, which can also support the maturation of other company-wide agendas such as ESG.

Another important starting point will be around DEI. The IT department at the typical enterprise is not the most diverse environment from any perspective. However, a recent 451 Research study finds that 2020 was a watershed year for DEI issues: Half of survey respondents report that their organization expanded their commitment to DEI during 2020, with around three-quarters having formal commitments to increase DEI in their workplaces overall. Formalizing the importance of DEI is an important step that makes organizations more accountable for results and outcome.

Ultimately, as more businesses commit more strongly over time to the spirit (and not just the letter) of ESG – promoting stronger fairness, inclusivity, reliability, safety, transparency, privacy and accountability across their organizations – technologies will be a crucial determinant of how successful they are.

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## Implications for Technology Suppliers and Service Providers

The technology (and IT) industry itself is no different; it is collectively placing a renewed emphasis on various aspects of ESG, with several of the large technology vendors 'recommitting' or updating their ESG mandates over the last year. The industry will have particular importance to the role ESG plays in the longer term for several key reasons. It has an outsized impact on the 'market cap' of the market overall – constituting 26% of the S&P 500 (as of May 28, 2021), more than double the next sector – giving it particular significance for the increasingly ESG-minded investment community at large. It is a significant employer globally and has a central role in transforming society through the creation of the digital economy – it needs to be a 'leader' by example here. The industry is also challenged by the growing interest in sustainability and social equity; it needs to become more diverse, inclusive and reflective of the societies that 'big tech' serves.

For example, [a 2020 report by S&P Global](#) noted that although growth in women's representation on boards and c-suites at tech companies has increased worldwide in the past 10 years, there is still a long way to go. The report found that women occupy less than a fifth of spots on boards of directors at tech companies – less than for the financial or industrial sectors. Additionally, the report found that companies with more women in the IT department tend to be further along with their digital transformation efforts, and that economic modeling suggests greater gender diversity is linked to stronger financial performance.

The IT industry is also a significant contributor to the global carbon footprint, and almost 60% of IT industry emissions come from the downstream use of products by customers, according to S&P Global Trucost data (based on the S&P Global 1200 Index, as of November 2020). This explains why it's also at the forefront of the corporate push for green energy globally, with the big five tech companies (Amazon, Apple, Facebook, Google and Microsoft) all setting targets to use 100% renewable energy. Microsoft plans to be carbon-negative by as early as 2030. The datacenter industry also deserves mention here. As more organizations offload the data and services their customers use into cloud computing infrastructure, the datacenter providers supplying key parts of that infrastructure consume significant amounts of energy. While their power consumption is increasingly being shifted to green sources, some elements of their operations are more difficult to switch. This challenge will drive innovation and make datacenter operators increasingly sophisticated players in the power markets.

As businesses organize around their ESG commitments, they will increasingly want to know not just that their suppliers themselves take sustainability issues seriously, but that the technologies and services they procure can directly support their own strategies. Suppliers will need to be clearer about the business return their customers can experience from using their technologies. Any trade-offs between, for example, performance and energy efficiency will need to be made explicit. Increasingly sustainability-conscious customers will identify attempts to 'green-wash' products and services. Suppliers will need to partner with their clients and meet them where they are in their ESG journey – which, as adoption matures, may mean getting to know their customers anew.

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# The 451 Take

ESG has emerged to become not only one of the hottest issues of our time, but potentially one of the most transformative for both industries and societies as well. As a result, we expect ESG to become a growing part of the information technology industry narrative over the coming months and years. As we show in this report, the impacts and implications of ESG on technology are both wide-ranging and material; in fact, there is almost no area of the segment that will not be impacted, or will not have a role to play in shaping the future. Some of those impacts – such as the building of sustainable datacenters – are more obvious and compelling. However, technology will also play a more subtle role across a much more expansive palette of ESG factors over the coming years that collectively will help to drive industry and societal change. The 451 analyst team will continue to explore these trends to help clients understand their impacts and implications on the ESG landscape as they evolve.

# Key Findings

This report details more than 30 important technology trends, looking at how they impact across these different groups across each of the 'E,' 'S' and 'G' dimensions. Included in our analysis are the potential impacts from the rollout of 5G, artificial intelligence (AI), the cloud, customer and employee experience technologies, cybersecurity, datacenters, data management and analytics technologies, and the Internet of Things (IoT). These technologies are influencing the ESG agenda in different ways, to varying extents and at different speeds. Some issues, such as the sustainability of datacenters, are clearly having a major bearing on ESG strategies today. But others are much more subtle, and their potential impacts will play out in the longer term. Among our key findings are the following:

- **Datacenter efficiency.** Half of datacenter operators say their investment in sustainability initiatives is being driven by customers interest, according to a global survey by 451 Research in 2020. The majority of service providers expect sustainability to become a key competitive differentiator in three years.
- **Ethical consumerism.** Around a third (35%) of respondents in 451 Research's [VoCUL: Tablets & PCs, Purchase Drivers & Motivators 2020 survey](#) say they are more likely to purchase electronic devices produced using environmentally sustainable business practices. Eighty-seven percent of these respondents are also willing to pay more for such a device.
- **Talent strategies.** Technologies are playing a growing role in employee engagement strategies. Thirty-five percent of employees would accept a new job if the only way it differed from their current job were the better availability of devices, applications and other productivity tools, according to our [VotE: WPC, Employee Engagement 2020 survey](#).
- **Supply chain governance.** Manufacturing companies are using digital twin and digital thread processes to shore up their supply chain governance: 68% have partially or fully deployed them across their operational systems, according to our [VotE: IoT, The OT Perspective, Use Cases and Outcomes 2020 survey](#).
- **Bias in AI.** Sixty-six percent of organizations with AI deployments are testing their models for bias either prior to or after deploying, according to our [VotE: AI & Machine Learning, Use Cases 2021 survey](#), illustrating the strong push for ethical and responsible AI.
- **Consumer data privacy.** Nearly half (46%) of consumers have reservations about sharing their personal data online, yet only 8% of businesses report having a dedicated data privacy team that has primary responsibility for data privacy and data protection, according to our [VoCUL: Connected Customer, Trust and Privacy](#) and [VotE: Data & Analytics, Data Management & Analytics 2020 surveys](#).
- **Dependence on 'smart' technology.** With 451 Research's [Industrial IoT Market Monitor](#) showing the number of industrial IoT (IIoT) devices nearly doubling over the next five years – with billions of 'smart' devices proliferating in consumer, retail and industrial markets – there are clear and growing environmental, social and governance risks across almost all aspects of human existence.

Understanding these and the other technology trends we detail in this report will be essential for anyone serious about ESG. Businesses and their technology suppliers, technology and corporate investors, regulators and public policymakers will all need a more comprehensive and nuanced view in the coming years around how the technology choices businesses make can impact their ESG goals.

# Navigate This Report

<b>ENVIRONMENTAL</b>	Environmental impacts are becoming a material issue in all industries, with businesses increasingly under pressure to manage those impacts and maintain transparency through appropriate monitoring and reporting.
<b>SOCIAL</b>	Social impacts on employees, suppliers and customers are also becoming a material issue in all industries and are directly linked to companies' reputation and brand equity, and their operational performance.
<b>GOVERNANCE</b>	Corporate governance systems ensure a company is managed in the interests of shareholders and other stakeholders, including the checks and balances that enable the Board of Directors to have appropriate control and oversight responsibilities.

## APPLIED INFRASTRUCTURE & DEVOPS

Click the ESG boxes throughout the report to return to this table

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## CLOUD & MANAGED SERVICES TRANSFORMATION

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### DATA, AI & ANALYTICS

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### DATACENTER TRANSFORMATION

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### INFORMATION SECURITY

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<a href="#">Trend 1: Digital Twins and Digital Threads Provide Data Transparency for ESG Goals</a>	E	S	G
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[Read the Methodology](#)

# Applied Infrastructure & DevOps

**Channel contributors:** Brian Partridge, John Abbott, Henry Baltazar, Mike Fratto, Eric Hanselman, Carl Lehmann, Jay Lyman, Christian Perry, Simon Robinson, Liam Rogers

The Applied Infrastructure & DevOps channel covers a wide spectrum of technologies that together form the modern IT infrastructure and DevOps stack, which cuts across public and private clouds, networks and edge environments. Modern hybrid IT infrastructure is increasingly abstracted, software-defined and programmable, which begets overall system ‘intelligence’ often assisted by applying machine learning to IT performance KPIs. Better intelligence can drive positive ESG outcomes in the form of more IT visibility, security and controls, which improves governance.

The convergence of discrete IT technologies (network, compute and storage) toward software-defined datacenters does not necessarily create less demand for power versus legacy setups – the opposite, in fact. The onus falls on modern infrastructure vendors across hyperconverged infrastructure (HCI), servers, storage and networks to accelerate efficiency developments and focus on innovations that can deliver sustainability and greater transparency at the system level. As ESG impacts are increasingly a component of vendor selection, this will be an area of competition as important as performance and a key focus of differentiation for system vendors.

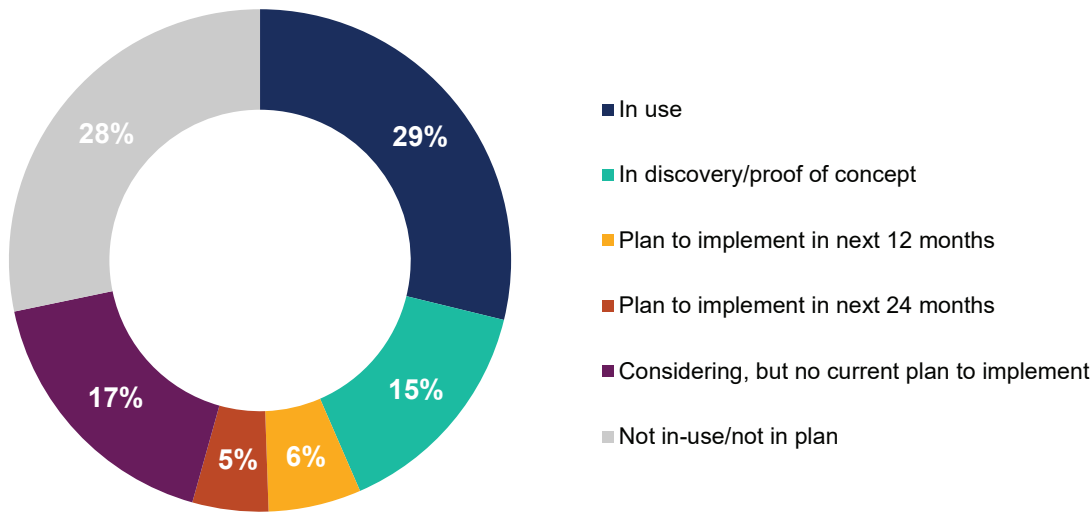
As we enter the 5G era of mobile computing, we anticipate a mixed bag of ESG outcomes, and some important questions remain. 5G performance characteristics will accelerate digital transformation across a wide range of industries and many of those outcomes will have positive ESG effects, but there are still open questions and work to be done. 5G vendors and network builders will increasingly need to compete based on their environmental impacts (energy efficiency, alternative energy sources, etc.) and transparency.

## Trend 1: Software-Defined Infrastructure Brings Power Concerns With Its IT Efficiencies

**Implication:** Software-defined infrastructure (SDI) is bridging the IT efficiency gap between on-premises enterprise and public cloud environments, but these inherently dense, fully utilized systems are increasing power requirements for many customers. These requirements will likely rise as more traditional infrastructure gets phased out in favor of SDI.

As enterprises work to build efficiencies into their IT ecosystems, the drive toward SDI is alive and strong. According to 451 Research's *Voice the Enterprise (VotE): Digital Pulse, Budgets & Outlooks 2021*, 29% of organizations have SDI in use, 15% have it in discovery/POC, and another 28% plan to implement it or at least are considering it, reflecting the continued uptake of technology designed to deliver more automated, intuitive control over systems (see Figure 1). However, while SDI can improve the overall productivity of IT teams by removing the burden of manual provisioning and other tasks, it does not necessarily mean that the infrastructure itself is efficient from a power perspective.

**Figure 1: Drive Toward SDI Is Alive and Strong**



Q. Please describe the level of usage within your organization for each of the following technologies – Software-defined infrastructure (SDI).

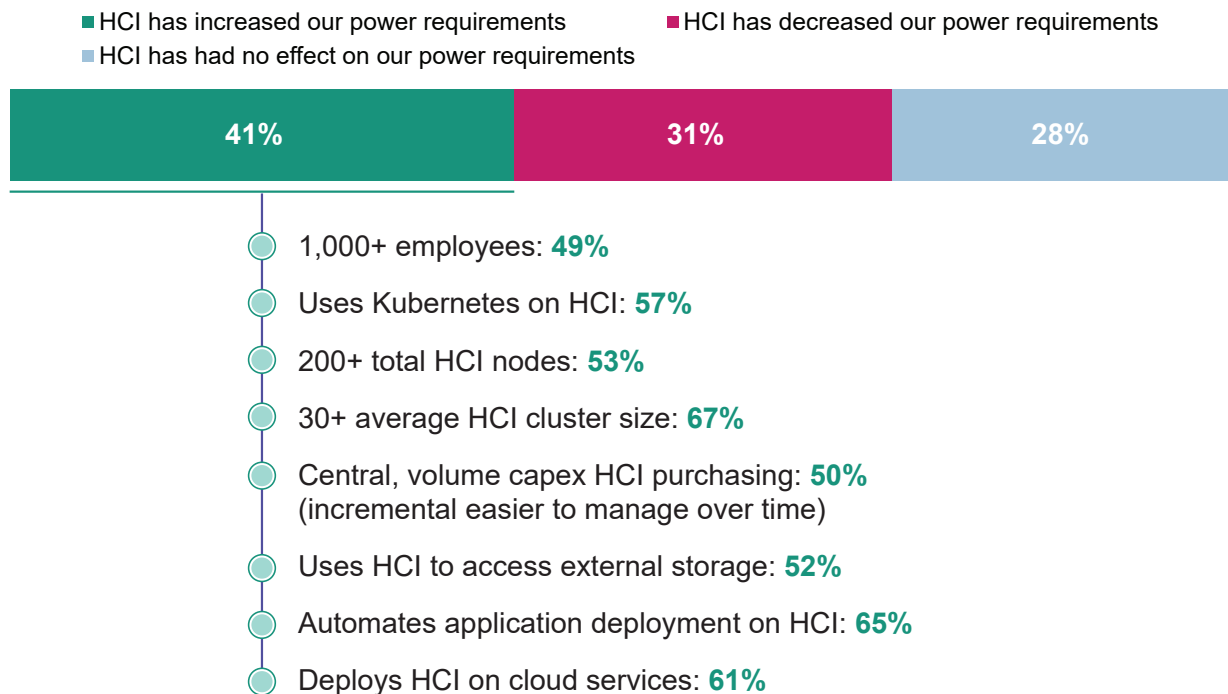
Base: All respondents, abbreviated fielding (n=184)

Source: 451 Research's Voice of the Enterprise: Digital Pulse, Budgets & Outlook 2021

On one hand, the shift into virtualized infrastructure has contributed to a smaller overall industry carbon footprint, as fewer servers are required to perform the same tasks as non-virtualized servers. On the other hand, the increase in utilization delivered by virtualization – and, increasingly, containers – has led to increases in rack density that can easily outweigh any benefits delivered on the physical footprint side. Perhaps nowhere is this more evident than with HCI, which is helping IT teams transform their day-to-day deployment and management of IT, but with a side effect that is unexpected for some adopters.

According to our *VotE: Hyperconverged Infrastructure, Technology & Platform Innovation 2020 survey*, 49% of HCI adopters with at least 1,000 employees say HCI has increased their power requirements (see Figure 2). Initial rising power requirements are likely seen as a fair tradeoff for the transformational capabilities inherent with SDI, but customers will raise a white flag – and potentially shift more infrastructure requirements to public cloud – if increased SDI adoption leads to power costs and associated environmental impacts that outstrip any operational benefits delivered by the technology. Nonetheless, most IT environments using SDI contain a mix of traditional and software-defined infrastructure, so it is nearly impossible for enterprise customers to yet gauge the impact of a fully software-defined environment. In the meantime, SDI vendors are advised to set expectations with customers so they can anticipate and better manage power requirements as they evolve along with infrastructure technologies.

**Figure 2: HCI's Impact on Power Requirements**



Q. To the best of your knowledge, please describe the impact of HCI on your organization's datacenter power requirements to date.

Base: HCI is in use or POC (n=137)

Source: 451 Research's Voice of the Enterprise: Hyperconverged Infrastructure, Technology & Platform Innovation 2020

## Trend 2: Mass Deployment of 5G Raises ESG Questions as Well as Answers



**Implication:** 5G will enable and drive digital transformation of several industries including, of course, the telecom industry. There is no shortage of potential use cases in which 5G connectivity, when combined with advanced user equipment and IoT sensors (using AI analytics), can play a meaningful role in driving better environmental (e.g., smarter factories, smart cities, autonomous vehicles), governance (e.g., better/intelligent instrumentation of assets/people) and social (e.g., telehealth, rural broadband, distance learning) outcomes across a wide range of stakeholders. However, there has been limited debate and study of the overall negative ESG impacts of covering the planet in high-performance 5G mobile networks.

While more energy-efficient than previous systems (as measured in kWh per GB delivered), 5G systems are expected to drive overall energy usage on a per-operator basis up rather than down. While 5G is expected to be more energy-efficient on a per-tower basis (and the OEMs play this up), there will be many more towers and much more data generated by these systems, which, in turn, could drive significant overall increase in carbon emissions.

5G networks fully realized require a very dense deployment topology because they make extensive use of mid- and high-band spectrum, so they will require extensive new tower builds. This means more physical locations and radio towers along with a refresh of ancillary infrastructure including antennas, small cells and 5G devices.

5G accelerates consumer and enterprise device proliferation, which does not promote longer lifespans – the opposite, in fact. Network evolutions drive an explosion of new devices and create a fresh push to upgrade existing smartphones and create billions more IoT devices. OEM suppliers are required to produce large numbers of new and complex devices, which sets the stage for labor and environmental (biodiversity) issues.

According to the [S&P Global Market Intelligence 5G Tracker](#), 13% of deployments are currently using millimeter wave for high-performance mobile broadband (including Verizon), but several more millimeter wave (MMW) deployments are planned globally for 2021 and beyond. The characteristics of high-band radio frequencies are different than those of low-band and mid-band frequencies used to support mobile services globally prior to 5G and enable the transmission of large amounts of data over short distances. MMW frequencies are generally deemed to be safe for short-term exposure for humans, but there still debate surrounding the potential for long-term negative bioeffects, including on animal ecosystems and insects.

### Trend 3: New Approaches to Rapid Enterprise Performance Intelligence Improve Compliance and Control



**Implication:** The discovery and automation technologies now used to intelligently redesign business and IT processes and enable them to make recommendations, predictions and decisions are evolving. They will enable real-time monitoring and proactive management of nearly every measurable business function within enterprises. A new generation of enterprise performance intelligence technology is on the horizon that can establish new financial controls for ESG governing criteria.

An emerging class of integrated technologies will provide the management teams of digital businesses new options that will enable them to quickly adapt to change, risk or opportunity. Digital business represents a transformation of product and service creation and delivery and can create entirely new businesses and business models. Many different types of technologies can make up a digital business, including cloud services, cloud-native architecture, agile software development, containers and microservices. These technologies accelerate the deployment of new adaptive IT infrastructure and application environments that now enable modern hybrid IT architecture.

Another class of technology rides above such adaptive infrastructure to enable digital business. It includes digital automation platforms that automate and deploy business processes; robotic process automation technology that automates workforce tasks and activities; and process discovery technology that examines data from systems of execution and workforce behavior to intelligently reimagine and redesign digital business operations based on actual execution data. Each now interoperate and employ a range of machine learning and AI technologies. Collectively, they enable enterprises to develop and deploy intelligent process automations that can also continuously capture execution and performance data, enabling them to become smarter and make data-driven recommendations, predictions and decisions.

When deployed and integrated, these technologies actually 'instrument' IT infrastructure, embedding within it means to capture, in real or near-real time, the data needed to visualize, analyze, monitor and control the performance and outcomes of digital business operations. This data can also feed other strategic business intelligence and activity dashboards employed to monitor and track business metrics, compliance measures and financial performance. Overall, these technologies enable a new form of digital awareness we refer to as enterprise performance intelligence.

# Cloud & Managed Services Transformation

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COVID-19 has been an opportunity for cloud to show its potential: According to 451 Research's [Voice of the Enterprise \(VotE\): Digital Pulse, Vendor Evaluations 2020](#), 53% of enterprises are using more cloud as a result of the pandemic. Cloud's ability to scale at will, by the hour, with outsourced management to a centralized provider has allowed companies to evolve to cope with the pandemic as best as possible. But these same qualities are opening up technology to the masses, not just those with capital and formal education. Anyone with a credit card and an internet connection now has access to advanced technology in an unprecedented manner. With the sheer volume of customers, hyperscale cloud providers have much to gain by increasing efficiency and lowering their cost bases, with a reduced carbon footprint as a fringe benefit. Cloud is the default venue for the younger generation of developers, an audience that is very aware of the world's environmental and social challenges. Over the next few years, cloud won't just be impacted by ESG issues – it'll be the driver of change. But the impact of quantum computing on IT looms on the horizon.

## Trend 1: COVID-19 Has Shown Cloud's Ability To Benefit Society



**Implication:** The on-demand, scalable model of cloud computing has provided work, schooling and entertainment to the masses, despite the rapidity with which COVID-19 spread. After the pandemic, this flexibility will provide more opportunities for those who have previously struggled with access to education, employment, healthcare and capital.

Over the course of the coronavirus pandemic, organizations have used cloud to maximum effect: 31% of enterprises have increased IT spending, compared to 19% that have decreased spending, according to 451 Research's [VotE: Digital Pulse, Coronavirus Flash Survey](#). Schools have had to run classes online, and healthcare facilities have had to schedule calls instead of in-person appointments out of necessity. Changing needs have encouraged innovation, and cloud – which can be provisioned remotely without capital – has allowed developers to rapidly build new services from all over the world.

If we can run remote clinics during COVID-19, why can't we use the same technology to allow those in remote regions to access healthcare information and even live consultations without the need to hire local doctors and build facilities? If we can provide students with access to university courses, why can't we provide under-represented and underserved populations with the means to build new technological innovations without capital, a good credit score or supportive networks of cronies? And if cloud lets us work from home, why can't we use it to provide a way for less wealthy communities to gain skills and even work remotely, to help sustain and grow local economies?

The economic power of cloud in the form of no-capex, pay-as-you-go, on-demand, scalable access to powerful technology can help realize these opportunities. Building schools for two communities costs twice as much as building one school; scaling an education website that can address the needs of a million students instead of thousands is a relatively small cost. This is crucial to addressing inequality by giving those who have traditionally not been able to access such services the ability to do so at very low or no cost. With no capital, physical materials or transportation needed, cloud can put services in the hands of those who need them. And hopefully, the lessons we learned regarding anywhere access during the pandemic can be harnessed for the common good.

Of course, it's not that simple in practice. But the cloud-driven approach to building the IT foundation needed to expand delivery of opportunity sets the stage by providing 24/7 access at low (or even no) cost. And the centralization of IT resources means the end users' devices don't need a huge amount of power or advanced technology to be useful. Ten years ago, would it have even been feasible for a woman based in a remote developing region to learn to code in her free time and then work remotely for a US-based tech giant? Today, it is at least possible. Sixty-seven percent of enterprises are expanding home-working policies for the longer term or permanently, according to our Digital Pulse: Coronavirus Flash Survey, enabling HR departments to cast a wider net when looking for talent.

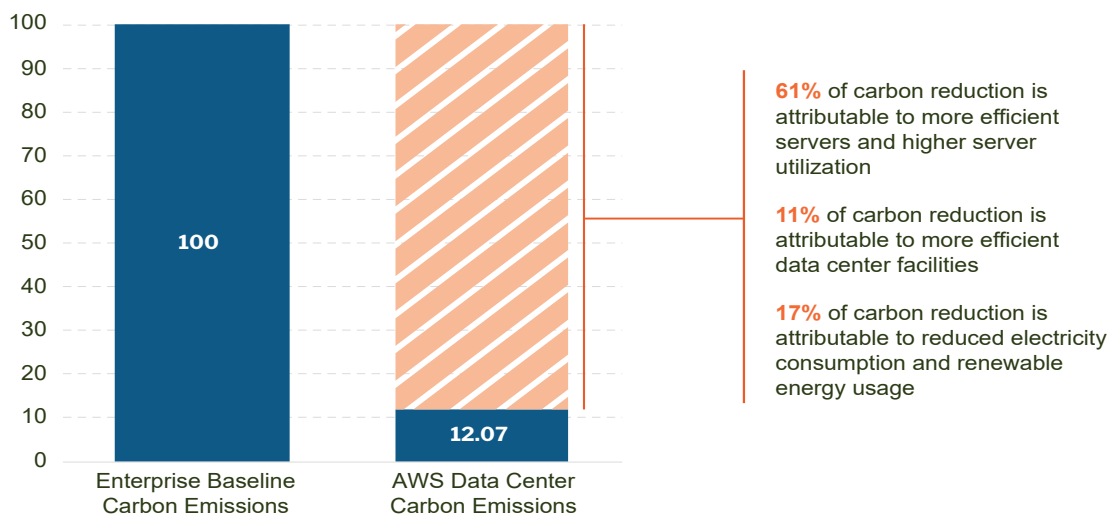
## Trend 2: Hyperscaler Efficiency Reduces Carbon



**Implication:** Along with achieving massive economies of scale, cloud providers are engineering datacenters for energy efficiency, with pledges to become carbon-neutral or even carbon-negative. This consciousness impacts the entire supply chain, from silicon to software.

Improvements in IT energy efficiency can come from better resource utilization, lower power consumption and greater reliance on renewable energy sources. In all these areas, AWS, Microsoft, Google and others have brought 'green IT' initiatives to the forefront. A 451 Research survey commissioned by AWS in 2019 found that these factors combined yielded an 88% reduction in carbon efficiency for workloads running in the cloud versus in the average on-premises enterprise datacenter (see Figure 1).

**Figure 1: Carbon Efficiency of AWS Infrastructure Compared to Surveyed US Enterprises**



Source: 451 Research custom research commissioned by AWS, 2019

Cloud providers largely rely on the same energy-intensive air-cooling technology that has been used for years, but the growing volume and density of devices in hyperscale datacenters has prompted reengineering to increase compute and storage capacity without a corresponding uptick in energy consumption. These efforts run the gamut from purpose-built silicon and servers with higher core counts to liquid cooling technologies that dramatically reduce the power needed to keep devices humming. The near-universal substitution of solid-state drives for magnetic disks is one example of this trend. IT customers are increasingly evaluating suppliers' efforts in this regard – a solid roadmap for reduced energy consumption indicates the potential for lower per-unit costs and market resilience.

At the same time, major hyperscalers and colocation providers have committed to making their datacenters carbon-neutral or even carbon-negative, and a big component of this involves purchasing and developing renewable energy. AWS relies heavily on on-site solar power and wind farms to power its datacenters in the US and Europe; Microsoft has pledged to be carbon-negative by 2030 and has tied executive compensation to progress on sustainability goals; and Google, which says it has been carbon-neutral since 2007, has pledged to use carbon-free energy in all of its datacenters by 2030. Much of this benefit is to win over carbon-aware buyers and even job candidates – but of course, cost savings from more efficient technology, lower electricity bills and an infinite supply of renewable energy drive profits margins.

### Trend 3: Service Providers Must Show a Social Conscience To Impress Talent



**Implication:** Enterprises count on service providers to stand in for skillsets that they do not have access to internally, but service providers are facing talent gaps of their own as barriers in attracting and retaining talent remain a challenge. Specialized, in-demand technical talent is more selective, and will consider an employer's social impact before committing to a new role. This will require service providers to evaluate internal values including diversity, equity and inclusion (DEI) and how they connect with the broader world.

The novelty of fully stocked snack bars and foosball tables in the office has long worn off, and the next generation of technology workers is demanding more substantive work-life benefits that support a culture of DEI. Individuals with specialized, in-demand skillsets – such as cloud-native, data analytics or security expertise – have their pick when it comes to roles and want to work for employers that align with their social values. Cloud service providers whose efforts in DEI are merely performative will fail to attract and retain diverse top talent, who are more likely to engage with employers that have strong policies around work-life balance.

Employers will also need to be more transparent in how they plan to address the gender gap that has widened through the coronavirus pandemic and improve leadership diversity. A Q3 2020 [survey from S&P Global and AARP](#) suggests that family-care policies can help an organization achieve gender equality. Women often bear a greater responsibility of caring for children and aging relatives – a situation that has become more acute through the pandemic. However, with few women in senior management roles, especially in the IT and cloud services industry, these policies are often not an organizational priority, further perpetuating the gender imbalance and potentially resulting in a lasting impact on innovation in the cloud services sector. Furthermore, with the COVID-19 pandemic accelerating digital transformation, it's even more important that the groups of people developing the apps, building the technology and designing the UIs are diverse and inclusive. 451 Research's recent [Voice of the Enterprise: Digital Pulse, Diversity & Inclusion survey](#) finds that while women may not yet be proportionately represented in organizations' IT departments overall, they are making strides in some of the more up-and-coming roles. Respondents point to application management/support and app developers/DevOps as the IT functions with the most full-time women employees, while IT infrastructure operations is the primary IT function featuring the fewest. In the digital economy, customer (and employee) experience rules – and greater diversity in IT means that companies digitizing their businesses have a better shot at getting it right.

### Trend 4: Quantum Computing Power Brings Great Responsibility



**Implication:** Capabilities of quantum computers could abridge personal privacy, while quantum researchers point to the boondoggle of AI ethics as cautionary tale.

Quantum computers are not merely faster computers. The capabilities and roles played by classical computers and future quantum computers differ, as quantum computers are well-suited to optimization tasks, and – generally – problems that involve exponential scaling. As with AI – which, as an emerging technology, is years ahead of quantum in commercialization – asking questions now about how fully realized, mature quantum computers could impact society is vital.



Early conversations about quantum computing center around the prospect of breaking public key encryption, the underpinning of any secure transaction conducted on the internet today, potentially allowing anyone with access to a quantum computer and man-in-the-middle access to network communication to decrypt and surveil the activities of any internet user. This works retroactively: Anyone (presumably, state actors) with access today can store encrypted sessions in hopes of decrypting data in the future.

Equity of quantum computing access is an open question: Much of the underlying science in recent private development of quantum computing was created at publicly funded universities. To what extent is private ownership of public resources acceptable? Quantum computing may likewise reopen debates over software patents.

An issue raised by the QC Ethics industry group is the expected scarcity of quantum computers over the next 5-10 years. Assuming, for example, that global warming is an existential threat, should the limited available quantum computing resources be used for commercial tasks, such as building financial trading models?

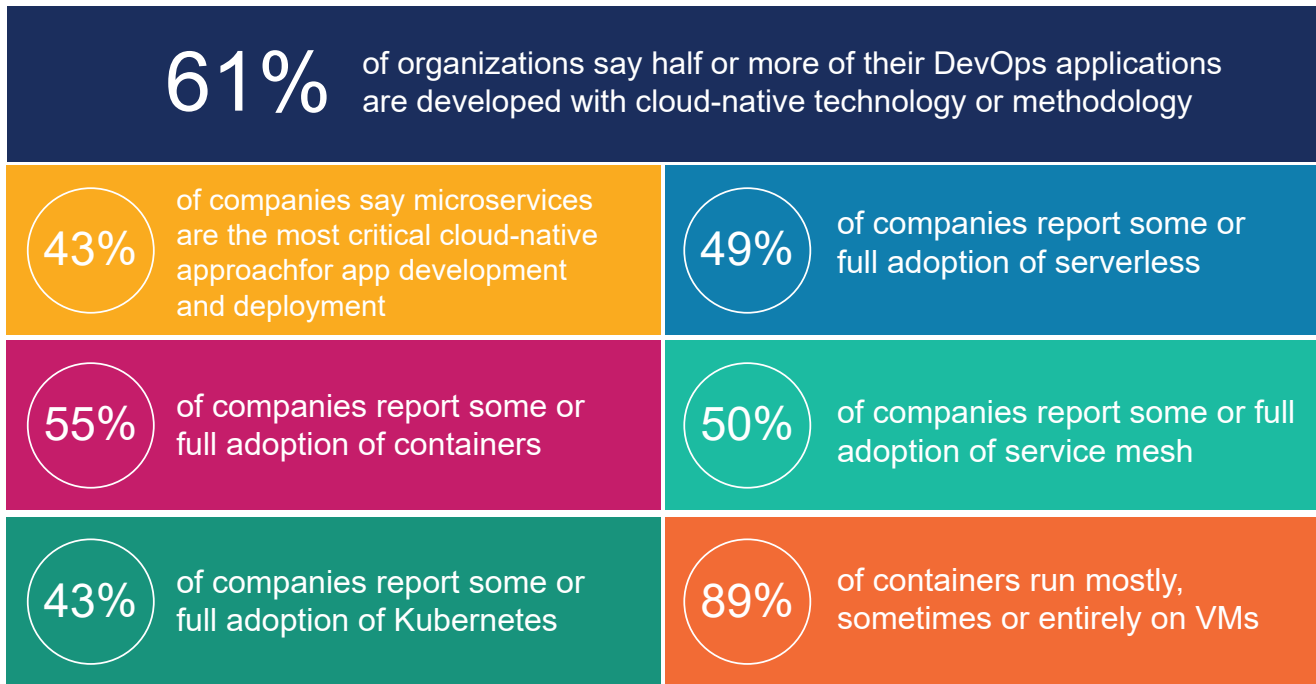
Likewise, purveyors of AI products selling to government agencies for surveillance purposes is a source of controversy; quantum computing hardware and algorithm vendors may become similarly embroiled in the event that government use of quantum computing is found to adversely affect minority or maligned populations. Quantum computing brings great power – but with that power comes great responsibility.

# Cloud Native

**Channel contributors:** William Fellows, Brian Partridge, Jean Atelsek, Henry Baltazar, Mike Fratto, Eric Hanselman, Nicole Henderson, Carl Lehmann, Jay Lyman, Fernando Montenegro, Christian Perry, Melanie Posey, Simon Robinson, Liam Rogers, Dr. Owen Rogers, James Sanders

One of the virtues of cloud native is that Kubernetes, open source and DevOps are change agents that break down institutional barriers and let organizations adapt and morph to take advantage of the possibilities of cloud and flexible IT foundations. Existing investments must be respected, and some workloads are better/more efficiently/more cost-effectively left on-premises (for now) – but that is a starting point, not the ending point. Those companies born as cloud natives, such as Uber and Lyft or Stripe and Wise, benefit from an organizational ‘clean slate’ that enables them to eat the lunch of traditional competitors. Conway’s Law, which dates back to 1967, posits that systems reflect the structure of the organizations that develop them. So while it’s a challenge, enterprises now need to embrace fundamental structural change to ‘turn the ship around’ and compete with more nimble cloud-native competitors. Their existing data assets/relationships will only take them so far into the future. The re-platforming to cloud native is well underway as the benefits of speed, agility, collaboration and governance are realized (see Figure 1), while 5G, edge and IoT are shaping up to be the outstanding market buildout opportunity.

**Figure 1: Cloud-Native Adoption Trends**



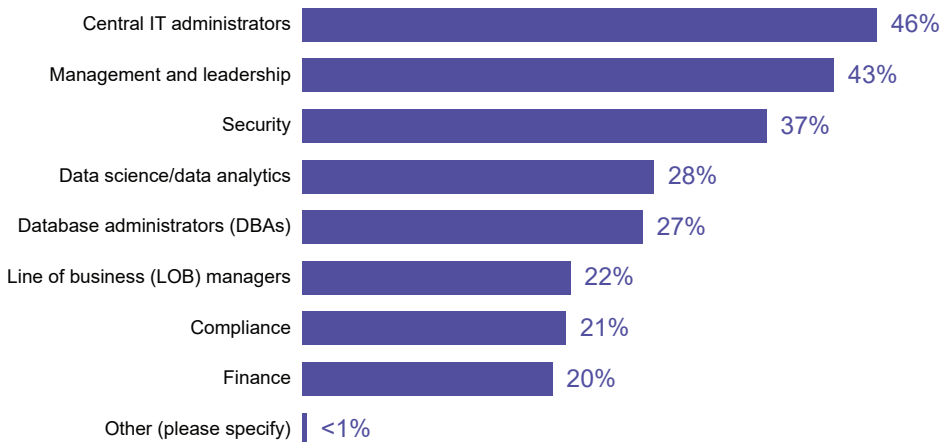
Source: 451 Research's Voice of the Enterprise: DevOps, Organizational Dynamics 2020

## Trend 1: DevOps Drives Governance and Collaboration

**Implication:** The cross-discipline nature of successful DevOps implementations will drive effective governance and synergy across a growing number of roles and teams of enterprise organizations, including management and leadership, traditional IT, security, compliance teams and others.

DevOps – the collaboration of software developers and IT operations teams for faster releases and more efficient IT management – typically starts with initial deployments that are then used as the basis for investing more broadly across teams within the company. While DevOps at its core is about developers and IT operators, our research indicates it tends to spread to an array of additional stakeholders, including management, leadership and traditional IT teams (see Figure 2). This is indicative of a more top-down adoption of DevOps and the fact that organizations cannot simply switch over to a DevOps approach for all of their applications and teams at once. DevOps teams must interface and integrate with these other stakeholders, further breaking down silos as was done originally for developers and IT operations teams.

**Figure 2: DevOps Spans the Organization**



Q. Beyond developers and IT operations, who are the primary stakeholders in your DevOps implementation? Please select up to three.

Base: All respondents (n=550)

Source: 451 Research's Voice of the Enterprise: DevOps, Organizational Dynamics 2020

In security, the DevSecOps trend means more security elements are being integrated earlier into software development and deployment processes so that organizations can drive quality and reduce risk. Our research shows DevOps and security teams do sometimes work together on DevSecOps requirements, but often these two different types of teams are still addressing those DevSecOps requirements independently, highlighting how silos can persist. Organizations must be aware of these boundaries across different disciplines and work to align both objectives and incentives to drive continuous improvement. This involves both technology and cultural issues, such as resistance to change, but just as the barriers between developers and IT operators can be broken down for improved communication and collaboration, it can be so for other teams. In doing so, enterprises can improve the transparency, effectiveness and continuity of governance across the organization.

## Trend 2: Open-Source Ethos Democratizes Cloud-Native Skills Acquisition



**Implication:** Thanks in large part to the open source community, cloud's democratization of access to compute and storage resources has been matched by a wealth of free or low-cost options for acquiring cloud-native know-how, including modern-day application development, data science and infrastructure management. Motivated individuals can easily tap into this rich vein of knowledge, and companies that incentivize employees and customers to expand their skills in cloud-native technologies benefit from the empowerment and business value this education can bring.

The flexibility and scalability that are the hallmarks of cloud computing have found powerful expression in the ability to share and acquire knowledge through a host of online platforms. A computer science degree from an elite institution or certification on a particular vendor's software or equipment still has value, but the options for acquiring skills to solve specific business problems at little or no cost are greater than ever.

A crowdsourced approach to improving software is a prized principle in the cloud-native ecosystem. The effects of this all-for-one and one-for-all attitude include:

- **Globalized standards:** Kubernetes container orchestration, Prometheus monitoring and Envoy service proxy have all achieved 'graduated' status within the Cloud Native Computing Foundation framework, giving developers and vendors a common substrate for building and refining their own open source or commercial offerings. These projects must continually prove their staying power in a broad community and amid changing conditions. The information exchanged as individuals review code, report issues and submit pull requests adds to the integrity of the project and addresses pain points in real-life applications. A recent month of commits to the Kubernetes project included top contributors from Germany, the US, Poland, Shanghai, Spain, Switzerland and Italy.
- **Ease of adoption and use:** Open source projects live and die based on their utility. Momentum comes from adoption, and from there ecosystem network effects can create a magnetic field attaching developers (and the companies they work for) to a preferred way of addressing common business problems.

Vendors recognize the power of accessible education to recruit users to their ecosystems. Tutorials, getting-started guides and credential programs allow skills development in areas where organizations are having trouble finding qualified personnel or want to retrain staff to thrive as IT systems undergo transformation. Companies that invest in business-specific training in essential technologies can reap returns in employee and customer engagement, new or improved products and future readiness.

## Trend 3: Serverless Delivers Operational Efficiency and Optimized Resource Use



**Implication:** The serverless and functions-as-a-service (FaaS) models of computing offer control over capacity and resources because execution is a function of demand, which can optimize energy consumption and deliver operational and economic efficiency.

In the serverless model – or more properly, 'provisionless' – the service provider runs the server and dynamically manages the allocation of machine resources to execute code that is packaged as functions (FaaS). Pricing is based on the actual amount of resources consumed by the execution of the function, rather than on pre-purchased units of capacity (as required by VMs). At the front end, serverless' pay-for-use pricing model (per millisecond) enforces a developer discipline for efficient code – indeed, many serverless offerings are accompanied by new developer enablement programs. It is the ultimate managed service because it scales according to exact demand – up and down to zero. Serverless has been a commercial reality since AWS's launch of Lambda in 2014, followed by other vendors. 451 Research's Digital Economics Unit completed [an extensive analysis of serverless computing](#) and concluded that the TCO of serverless is likely to be less than that of VMs in many workloads, even compared with containers hosted on VMs. One consequence is the emergence of 'serverless-first' approaches to application deployment (similar to 'cloud-first' before it) as the business benefits become clear.

There's a tremendous amount of hype around serverless. The economic and environmental assumptions here are of course concerned with the consumption of services. The complete picture requires confirmation that service providers process FaaS requests in the most optimal (efficient) conditions. In the serverless model, service providers can reorganize their equipment in any way they choose to support those requests without the consumer of those services ever knowing. The cloud service providers and other serverless vendors have yet to break out any information about service efficiency when it comes to energy use to support this model of compute. However, its importance and growth was underlined at re:Invent 2020 by (then) Amazon Web Services CEO Andy Jassy, who said "Right now, if you look inside Amazon, and you look at all the new applications that were built in 2020, half of them are using Lambda [AWS's FaaS offering] as their compute engine."

Regardless, we believe serverless enables organizations to deliver incremental value faster because development teams can ship software on quicker release cycles as they do not need to be concerned with infrastructure and other technology debt. We anticipate there will be an important sustainability/environmental outcome of using serverless versus 'serverful' approaches as its importance grows. As serverless technology innovations continue apace, the question for the industry is ultimately how much compute requirement will eventually go serverless.

## Trend 4: Cloud-Native Architectures Drive Efficiency



**Implication:** Cloud-native architectures can scale automatically in tiny increments to maximize server utilization and reduce waste while improving the application experience.

The centralization of IT resources via the cloud paradigm can reduce carbon footprint compared to distributed technology. As an analogy, a bus might produce more carbon than a car, but clearly a bus packed with 20 people is far more carbon-friendly than 20 cars. Similarly, a pool of servers shared by thousands of applications is likely to be more cost- and carbon-efficient than thousands of servers in thousands of datacenters. With cloud providers having the benefit of economies of scale, they are also better placed to use renewable energy and improve efficiency. Increasingly, we are relying more on technology – but with cloud, it means more people are choosing to get on the bus instead of driving alone.

Scalability is a major benefit of moving to cloud, where compute and storage resources can be adjusted based on usage. But to do this, applications must be broken up into a form of 'units' that can be placed side-by-side with others to increase server utilization. The smaller the units, the easier it is to take advantage of space available on a server. And the more utilized the server, the less energy is wasted.

Breaking applications into components that can be separately scaled, updated and managed is a key tenet of cloud-native architectures. Autoscaling groups add/remove VMs as usage thresholds are approached; containers fit workloads more efficiently into VMs and require less overhead to operate; and event-driven architectures (which use triggers, such as a database change or website registration, to execute functions as needed) manage scalability automatically without manual intervention. When used in combination, this set of cloud-native architectural principles allow applications to be managed efficiently at scale while optimizing resource usage and eliminating waste.

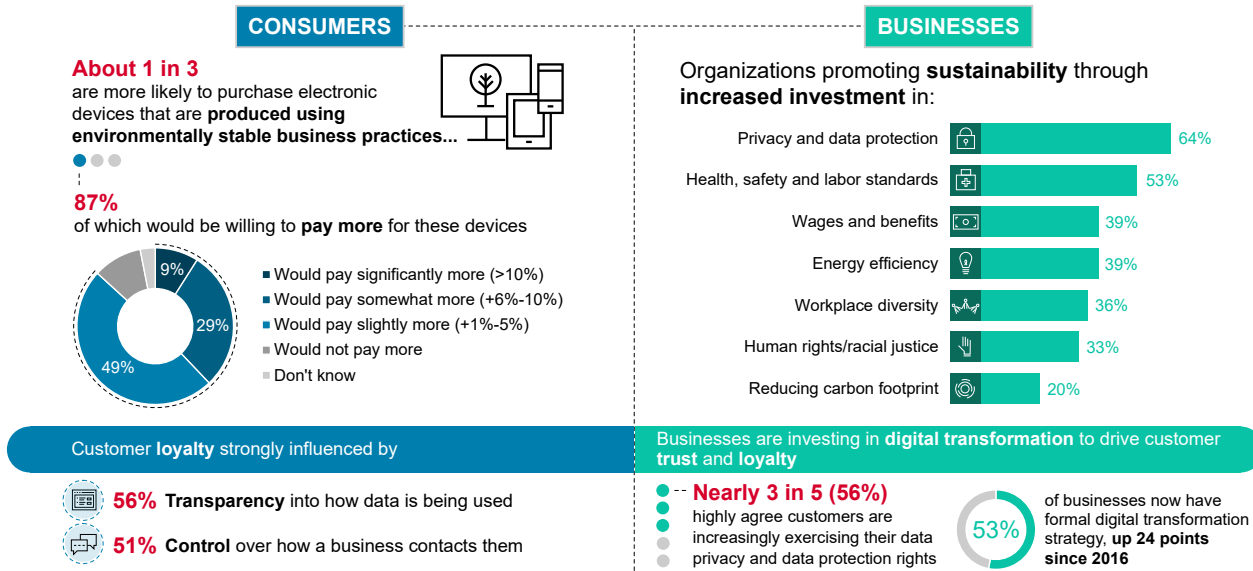
# Customer Experience & Commerce

**Channel contributors:** Jordan McKee, Sheryl Kingstone, Haley Brown, Bruce Daley, Scott Denne, Jessica Montgomery, McKayla Wooldridge

Wider social changes are manifesting themselves in a new consumer ethos. Consumers are prioritizing brand values and experiences over price and products (see Figure 1). Political advocacy is also spilling into brand awareness for many consumers as advocates call for boycotts of certain companies based on their stance on social issues. More than half of consumers in our surveys agree that transparency is a key driver of loyalty. To remain relevant in the eyes of the consumer, businesses are reducing their carbon footprint, encouraging workplace diversity, and investing heavily in data privacy and protection. We also find companies that are taking steps to allow consumers to reaffirm their commitment to environmental and social issues at checkout are improving conversions and driving revenue growth.

**Figure 1: Consumer and Businesses ESG Priorities**

**71%** of merchants cite a **rise in their customers' expectations of their organization** over the past 12 months



Q. Over the past 12 months, how would you describe the change in your customers' expectations of your business? Base: All respondents (n=258) Source: 451 Research's Voice of the Enterprise (VoTE): Customer Experience & Commerce (CXC), Merchant Study 2020 | Q. How likely are you to purchase electronic devices that are produced using environmentally sustainable business practices? Base: All respondents (n=1,033) Q. Would you be willing to pay more for an electronic device that was produced using environmentally sustainable business practices? Base: Respondents who are likely to buy an eco-friendly device (n=356) Source: 451 Research's VoCUL: Endpoints & IoT, Consumer Tablet & PC Trends (Leading Indicator), Purchase Drivers and Motivators 2020 | Q. On a scale of 0-10, please rate the degree to which each of the following factors would influence your loyalty to a given retailer or merchant, where 0 is no influence and 10 is strong influence? - Transparency into how my personal data is being used Base: All respondents (n=1,256); Control over personal preferences for how a business contacts me Base: All respondents (n=1,256) Source: 451 Research's VoCUL: Consumer Population Representative Survey, Connected Customer, Trust & Privacy 2020 | Q. How would you describe your organization's level of investment – if any – to promote sustainability in each of following areas? Base: All respondents (abbreviated fielding) (n=548-551) Source: 451 Research's Voice of the Customer: Macroeconomic Outlook, Business Trends, Automation and Technological Change 2020 | Q. On a scale of 0-10, do you agree or disagree on each of the following situations facing your organization's customer experience strategies? - Customers are increasingly exercising their data privacy and data protection rights (e.g., opt-out, data deletion) Base: CXC respondents (n=460) Q. Which of the following best describes your organization's status with regards to a digital transformation strategy? Base: All respondents (n=502) Source: 451 Research's VoTE: CXC, Digital Maturity 2020

## Trend 1: Consumers Reward Strong Business Commitments to ESG



**Implication:** Consumer demand for businesses that focus on ESG is rising, which is impacting loyalty and retention initiatives.

Many consumers are making ESG issues a part of their consideration when selecting brands and/or products. Around a third (35%) of respondents in 451 Research's [VoCUL: Tablet & PC Trends, Purchase Drivers and Motivators 2020](#) survey are more likely to purchase electronic devices (e.g., smart speaker, computer, smartphone) that are produced using environmentally sustainable business practices, and 87% of these are also willing to pay more for a device produced with these business practices. Environmental pressure is among the more well-known ways in which consumers advocate for change with brands. This is already reshaping a variety of industries such as retail, automotive, travel and hospitality, quick-serve restaurants and consumer packaged goods. Issues such as sustainability, clean energy and simplicity are clear values gaining momentum over the next three to five years as consumers prioritize brand values and experiences over price and products. All things equal, brands with a less ethical and environmentally friendly strategy are likely to lose out to those that have prioritized these areas.

Demands for ESG initiatives impact the entire value chain, from sustainable food sourcing to packaging, with specific programs geared to improve social standing, reputation and brand equity. These include carbon footprint reductions; diversity, equity and inclusion; and fair trade. Political advocacy is also spilling into brand awareness for many consumers as advocates call for boycotts of certain companies based on their stance on social issues. For example, Chick-Fil-A dropped donations after LGBTQ rights advocates called for a boycott of the company for supporting charities that opposed same-sex marriage.

Issues such as trust and privacy are now part of the broader governance systems for ensuring data security. Establishing and maintaining trust with consumers is contingent upon two key principles: transparency and control. More than half (56%) of consumer respondents to our [VoCUL: Connected Customer, Consumer Representative, Trust & Privacy 2020](#) survey agree that transparency into how their personal data is being used would make them more loyal to a given retailer or merchant, while 51% say control over their personal preferences for how a business contacts them would increase their loyalty. Transparency and control are at the heart of data privacy practices, and are key drivers of loyalty.

ESG pressures from consumers are impacting business decisions and increasing investments. We find that 20% of businesses are reducing their carbon footprint, 36% are investing in workplace diversity and 64% are increasing investing in data privacy and protection, according to our [Voice of the Customer: Macroeconomic Outlook, Business Trends, Automation and Technological Change 2020](#) survey. ESG initiatives are now a critical element for an organization's ability to create value for all stakeholders of the business. It's important to view the business through an ESG lens to measure and quantify the impact of initiatives through eyes of customers to maintain a competitive advantage.

## Trend 2: Environment and Social Factors Emerge as Potential Influencers in Checkout Conversion



**Implication:** Environmental and social factors are increasingly top-of-mind for consumers as they make decisions on which products to purchase. Taking steps to surface a commitment to these themes at checkout has the potential to help businesses increase conversions and drive revenue growth.

With 71% of merchants citing a rise in their customers' expectations of their organization over the past 12 months according to our [Voice of the Enterprise \(VotE\): Customer Experience & Commerce \(CXC\), Merchant Study 2020](#) survey, it's clear that consumers today are holding businesses to a higher set of standards. While it's simply good business practice to take an ethical approach to social and environmental issues, we believe that clearly surfacing a commitment to these themes during the buying journey shows growing potential to improve conversions.

Many businesses are already seeing results from promoting social and environmental causes in their 'top of the funnel' marketing messaging. Unilever, for instance, noted in 2018 that compared to the rest of its business, its most sustainable brands were growing 46% faster while generating 70% of the company's revenue growth. We see an emerging opportunity to align with social and environmental causes closer to the point of conversion. Notable examples include:

- **Stripe Climate.** Stripe merchants can elect to have a percentage of their sales automatically contributed to projects dedicated toward removing carbon dioxide from the atmosphere, and they can promote their involvement on their Stripe-hosted checkout page. In preliminary tests earlier this year, Nomad List observed an increase in signup conversions when it advertised a 5-10% donation during customer enrollment.
- **eBay for Charity.** eBay sellers can donate 10% (or more) to a selected charity, and in return for participation, add a 'charity ribbon' to their product listing. They may also get their item featured in eBay's Charity Shop. Items sold as part of this program may sell faster and generate a higher average order value, according to eBay.
- **Carbon Checkout.** Through commerce platforms such as Shopify, merchants can enable their customers to offset the carbon footprint of their order through a one-click donation at checkout. Several merchants, such as BuildASoil, have commented publicly on the positive customer feedback they've received since enabling Carbon Checkout.

As businesses look to level up their conversion strategies, promoting a commitment to ESG at or near checkout shows emerging potential to improve customer sentiment during the most pivotal moment of the shopping journey. Payment processors and commerce platforms should explore ways to help merchants act on this trend by making it easier to address and promote social and environmental causes during the customer's buying journey.

### Trend 3: Digital Transformation Investments Improve Measurement and Delivery of ESG Initiatives Related to Customer Experience



**Implication:** We expect that businesses' existing investments in digital transformation to improve customer experience (CX) will help to support the measurement of ESG initiatives related to operational effectiveness, customer service responsiveness, and data protection and privacy.

For many years, businesses have made sizeable investments in digital transformation to better measure and deliver a consistent customer experience. According to our [VotE: CXC, Digital Maturity 2020](#) survey, 53% of businesses have a formal digital transformation strategy and are actively digitizing their business processes and technologies. This is up 24 points from 29% of businesses in 2016, indicating that it has consistently been a high investment priority over the past few years. These investments already focused on operational effectiveness and customer service responsiveness to ensure business profitability and competitive advantage. For example, CRM, technology for managing customer relationships, will always remain an essential application for many businesses, from large enterprise providers to niche providers targeting small businesses or industry verticals. According to our [VotE: CXC, Vendor Evaluations 2020](#) survey, nearly 52% of businesses have already deployed a CRM application, while another 22% are considering a redeployment. Businesses are attempting to overcome previous failures, looking to become more agile, intelligent and data-driven to ensure regulatory compliance for data protection and customer privacy.

According to our [VotE: CXC, Organizational Dynamics & Budgets 2021](#) survey, improving customer service for retention (59%) and growing revenue from existing customers (54%) are top business objectives. They have remained consistent since our initial fielding in 2019. The prioritization of retention ahead of explicit revenue indicates a broader change in the organizational dynamics around how the business justification and value of CX investments are perceived. Data also plays a pivotal role in delivering optimized CX across the customer journey. Many businesses have been striving toward real-time decision-making for at least two decades, but only 12% of the market actually makes nearly all CX decisions data-driven in real time. Having a successful, data-driven organizational strategy is key to reaching CX digital maturity. The percent of digitally driven organizations with a formal data-driven strategy (71%) is now almost triple compared to those that are digitally delayed.



As businesses undergo digital transformation to become data-driven, they are confronted with a changing data privacy climate and are feeling the effects of these broader market changes. Consumer trust requirements put privacy and governance at the forefront. To reap the benefits of their data-driven investments, businesses must overcome the complexities and intricacies associated with data privacy. Nearly 3 in 5 respondents (56%) to our Digital Maturity survey highly agree that their customers are increasingly exercising their data privacy and data protection rights (e.g., opt-out, data deletion, etc.). But many businesses are struggling to provide consumers with greater agency over their data. Almost half (47%) of enterprise respondents in our Vendor Evaluations survey highly agree that when a customer exercises their regulatory right to data access or deletion, their organization has difficulty locating all of the relevant data. Complexity associated with compliance is already a significant barrier to business growth and is only subject to increase. Nearly half (45%) of enterprise respondents to our Digital Maturity survey have reduced their customer engagement efforts in certain geographic markets due to regulation.

The shift to data-centric operations to deliver more contextually relevant experiences accelerates the need to gather insight on macro trends such as environmental sustainability, social factors and trust to remain relevant in the eyes of the consumer. Additionally, measuring the impact and effectiveness of ESG initiatives will be imperative to ensuring they deliver value for internal and external stakeholders alike.

# Data, AI & Analytics

**Channel contributors:** Matt Aslett, Nick Patience, Paige Bartley, Rachel Dunning, Krishna Roy

Data and analytics are integral to ESG in enabling organizations to measure their performance relative to key targets, benchmark themselves against other companies, and measure and model potential improvement. Not all ESG factors are inherently quantifiable, but key trends such as energy consumption, emissions and environmental footprint, along with employee diversity and wellbeing, can and should be measured to identify goals for improvement.

The lack of regulatory requirements and standardization in relation to reporting ESG data means that comparing performance across different companies is easier said than done, however. This has the potential to prompt questions over data quality, as well as disputes over accuracy, and an inability to reach firm conclusions on progress.

Additionally, the use of data – and AI in particular – also raises potential social and governance concerns. While AI/machine learning (ML) is generally perceived as having a positive impact on society as a whole (see Figure 1), there are questions over ethical use cases for AI (such as facial recognition and user profiling), as well as issues related to the responsible use of models (including fairness, inclusiveness, reliability and safety, transparency, privacy and security, and accountability) and the energy efficiency of large-scale deep learning models.

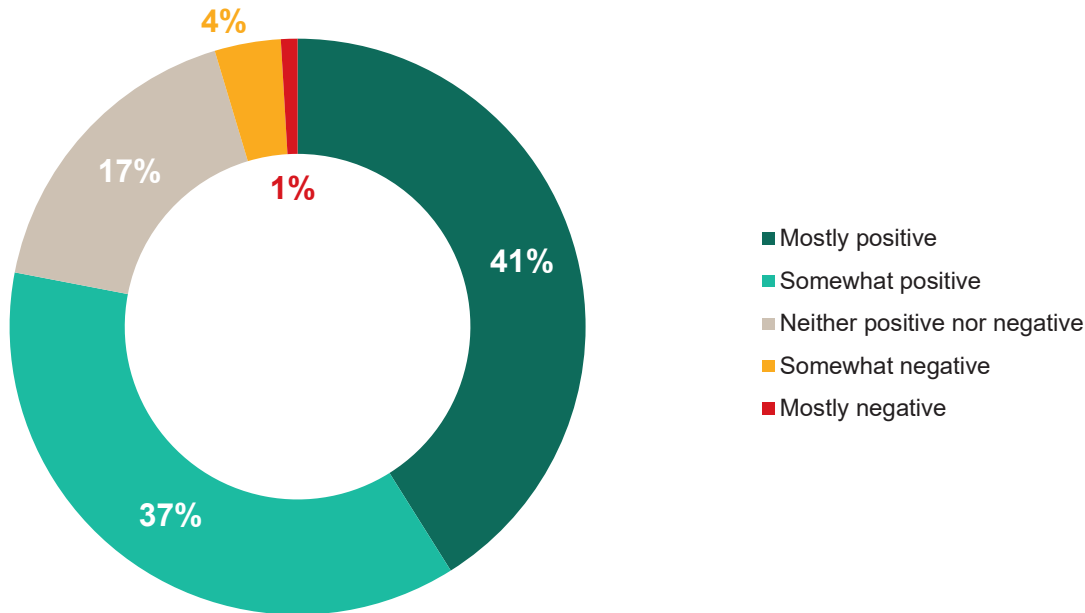
## Trend 1: Increased Awareness Drives Increased Focus on Ethical and Responsible Use of AI



**Implication:** AI has the potential to be positively transformative, but any tool can be misused in the wrong hands. Even if a use case for AI is considered to be ethical, there remain issues that need to be addressed in terms of responsible use of models to mitigate against bias (particularly gender and racial) and ensure models are used fairly and in a transparent manner.

AI has become an enabling technology for many enterprises in the digital era. According to 451 Research's [Voice of the Enterprise \(VotE\): AI & Machine Learning, Use Cases 2021](#) survey, 78% of respondents believe that AI will have a positive impact on society as a whole (see Figure 1), and adoption metrics continue to climb each year.

**Figure 1: Perceived Impact of AI and Machine Learning on Society as a Whole**



Q. Do you think the impact of artificial intelligence/machine learning will be positive or negative on each of the following? - Society as a whole

Base: All respondents (n=969)

Source: 451 Research's Voice of the Enterprise: AI & Machine Learning, Use Cases 2021

However, those who hope to capitalize on AI's transformative potential include bad actors who may try to exploit the technology for malicious purposes such as social engineering or cyberattacks. It's crucial that enterprises familiarize themselves with the methods in which these technologies can be exploited and build safeguards against them.

Even in the absence of bad actors, AI technology has the potential to be harmful, and as a result, there is a strong push for ethical and responsible AI. Facial recognition technology in particular has been under the microscope as of late due to algorithmic biases that have resulted in profiling, discrimination and wrongful arrests. In response to cases like this, enterprises are becoming increasingly aware of the importance of bias mitigation and transparency in their models.

According to the Use Cases survey, 66% of respondents indicate their organization tests models for bias either prior to or after deploying. This is a slight increase from last year, but still leaves over a third of enterprises that aren't testing for bias at all.

A critical step in eliminating model bias is being able to detect it in the first place. AI has long operated in a 'black box' environment with limited visibility into how or why decisions are made, and enterprises have just recently started to pull back that curtain, democratizing AI to make it more accessible and governable.

## Trend 2: Ethical and Responsible Use of Personal Data Can Become a Differentiator



**Implication:** Consumers are becoming acutely aware of data privacy, data security and related online data protection issues. They are also being granted more rights via regulations to exert control over the personal data that is collected from them. Responsible and ethical use of personal data is no longer just an obligation for enterprises, but a potential competitive differentiator.

Nearly half (46%) of consumers report having reservations about sharing their personal data online, but view doing so as unavoidable, according to 451 Research's *VoCUL: Connected Customer, Trust & Privacy 2020* survey. This public wariness puts pressure on the enterprise to provide proper stewardship of personal information if it is to cultivate trust with customers and foster long-term profitable relationships. Yet based on 451 Research's *VotE: Data & Analytics, Data Management & Analytics 2020* survey, only 8% of respondents report that their organization has a dedicated data privacy team that has primary responsibility for data privacy and data protection. There is a mismatch between consumers' perceptions and concerns and enterprises' ability to execute on data privacy requirements.

With high-profile data breaches and privacy violations making frequent headlines, we expect consumer awareness to continue to rise as individuals are granted more granular rights for the control and consent of personal information. For the enterprise, this means that simply meeting regulatory requirements is no longer sufficient; building a trust-based relationship with customers that allows for the voluntary exchange of data becomes a competitive differentiator.

Doing so will require a re-imagining of data management and integration practices. Today, for instance, many organizations automatically ingest personal data from third parties to populate internal databases and integrate with existing data sources. Even if a consumer were to request deletion of their data, there is a high probability that much of their data would be repopulated automatically after the initial deletion.

First-party data, collected directly from the customer or consumer with explicit consent, tends to be highest in quality. Ethical collection – and use – of this data forms the foundation for the trusting long-term relationships that have a higher probability of profitability. As such, organizations need to be champions for data stewardship rather than abiding by the footloose philosophy of collecting or analyzing data and 'asking for forgiveness later.'

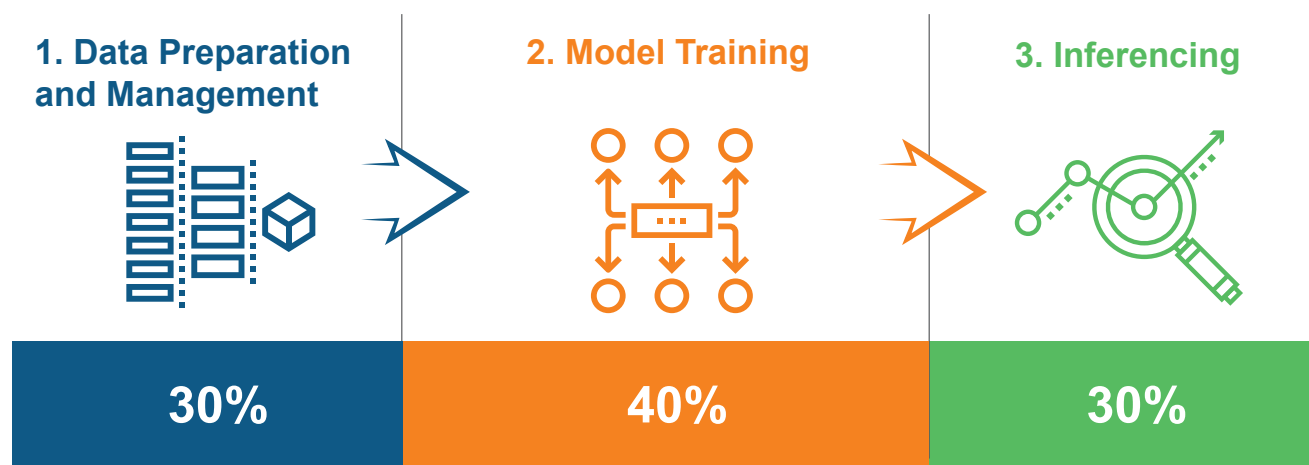
### Trend 3: Increased Energy Efficiency Concerns Impact Data, AI & Analytics

**Implication:** The resources required to run enterprise analytics projects at scale – especially deep learning models – consume large amounts of energy, to the extent that they could arguably be considered an environmental risk in their own right.

Analytics, including ML, has a key role to play in helping companies measure and understand their environmental footprint, as well as model potential improvements. However, like any software programs, analytics workloads consume resources, and the scale of resources required to build and train ML models in particular can be significant.

Data from 451 Research’s VotE: AI & Machine Learning, Infrastructure 2020 survey indicates that model training is seen as the most demanding phase of the ML process by 40% of enterprises, with 30% citing data preparation and management and another 30% citing inferencing (see Figure 2).

**Figure 2: Demands Placed on Infrastructure by Various Stages in the Machine Learning Process**



Q. Which of the following stages of the machine learning process [is or do you anticipate being] the most demanding on your infrastructure?

Base: ML is in production or proof of concept, or there are plans to use ML in next 12 months (n=668)

Source: 451 Research’s Voice of the Enterprise: AI & Machine Learning, Infrastructure 2020

The resources required to train the very largest deep learning models can be enormous. It has been reported that OpenAI’s GPT-3 175B model required 3.14E23 FLOPS of computing for training, for example. Meanwhile, academic research has shown that the level of carbon emissions involved can be significant (in one case, the equivalent of the lifetime carbon dioxide emissions of five cars).

The sort of large language models involved are the preserve of academia and the AI industry giants and, in comparison, a typical enterprise ML initiative is not going to have anywhere near as large an environmental footprint. That does not mean it should be ignored, however.

While the environmental footprint of a single short car journey pales into insignificance compared to a transatlantic flight, society has come to recognize that the collective impact of millions of short car journeys makes the necessity of each individual journey something worthy of consideration. Similarly, it is possible that the collective impact of millions of individual small ML and analytic models will become more widely recognized in the future, leading enterprises to at least consider the environmental impact of each individual model.

## Trend 4: ESG Data Quality Requires Regulatory Standards



**Implication:** The lack of regulatory requirements and standardization in relation to reporting ESG data leads to inevitable questions over data quality, raising the potential for disputes over accuracy and an inability to reach firm conclusions on progress.

Data processing and analytics have a key role to play in enabling enterprises and governments to measure trends related to factors such as energy consumption, emissions and environmental footprint – along with employee diversity and wellbeing – and set goals for improvement.

There is no shortage of data available related to ESG factors. As S&P Global (451 Research's parent organization) has noted, approximately 90% of companies in the S&P 500 publish sustainability reports. However, agreed standards on what should be reported – and how – are rarer.

As such, it is inevitable that there is potential for discrepancies between the data that companies disclose voluntarily and the data that is subject to regulatory scrutiny. Only 16% of companies in the S&P 500 reference ESG factors in their regulatory filings.

This lack of regulatory requirements and standardization in relation to ESG data has the potential to raise questions over data quality, prompt disputes over accuracy and hinder the ability to reach firm conclusions on progress. At the very least, it means that comparing data from different companies can be difficult.

While regulators are stepping up to provide recommendations and frameworks for reporting ESG factors, in the interim independent data and service providers are stepping in with their own methodologies. These are arguably just stop-gap measures, however, that do not diminish the need for longer-term regulatory and data reporting standardization.

# Datacenter Services & Infrastructure

**Channel contributors:** Kelly Morgan, Dan Thompson, Mai Barakat, Soon Chen Kang, Leika Kawasaki, Perkins Liu, Craig Matsumoto, Rahiel Nasir, Agatha Poon, Jonathan Schroth, Pedro Schweizer, Stefanie Williams

The datacenter industry is seeing pressure from multiple angles not only to source cleaner energy, but also to run more efficiently. This 'squeeze' is coming from governments enacting new regulations on efficiency and setting future capacity limits, as well as from customers that increasingly seek to improve their own carbon footprints. The good news is that infrastructure equipment manufacturers are innovating new ways to improve datacenter efficiency and leased datacenter providers stand to benefit, as enterprises will likely look to leased facilities to help them improve their carbon footprint in the future.

## Trend 1: Governments Continue To Place New Environmental and Energy Consumption Restrictions on the Datacenter Industry



**Implication:** In some countries, governments have placed efficiency regulations on new datacenters and limits on future capacity, effectively limiting supply. As ongoing digital transformation efforts continue to drive new levels of power consumption globally, governments will look to implement and increase regulations on datacenters, as they do other industries.

The rapid growth of datacenters has drawn attention to their impact on the environment in recent years, and we have seen several governments enact restrictions on the datacenter industry. These include Amsterdam, Beijing, Shanghai and, most recently, Singapore. While the policies vary slightly market by market, the underlying message is clear: Datacenters consume a lot of energy and need to be more efficient. To that end, most policies include some aspect of a power usage effectiveness (PUE) restriction, a measure of how efficient a datacenter is, where datacenters must show that they meet or exceed a particular PUE value. In addition, Amsterdam, Beijing and Shanghai have set restrictions on new datacenter supply by limiting electricity that can be used to power them, with the Chinese cities also employing a complicated licensing and auditing structure. Amsterdam and the Chinese cities have also limited where facilities can be built. Singapore has enacted tighter PUE regulations, is considering a capacity cap, and is also said to be considering asking providers to report their overall carbon footprint within the country, with the goal of becoming carbon neutral. While no official policy has been set and the government has committed to lifting the current moratorium this year, it is notable that the country is considering such a major step. It seems clear that the main operators must drive industry-wide change and improve sustainability, or face increasingly widespread and severe regulation.

Most government attention is focused on global greenhouse gas emissions, chiefly carbon dioxide, which is the biggest component of a datacenter's environmental footprint. Major datacenter campuses consume tens of megawatts of electricity, comparable to heavy industry, to power tens of thousands of servers, storage systems and network devices. Prime datacenter locations have attracted clusters of such campuses, putting strain on the electrical grid, using power generated from fossil fuels (in many cases), contributing to noise pollution and climate emissions with large-scale diesel generators and cooling systems and using vast amounts of concrete and other environmentally unfriendly materials in construction.

Service providers argue that on balance their activity can help reduce, rather than increase, overall emissions by replacing enterprise datacenter infrastructure that is typically less efficient. Indeed, modeling performed by 451 Research suggests that moving applications from on-premises enterprise infrastructure to cloud services can potentially reduce the IT energy footprint by as much as 70–80%. Leased and cloud datacenters are generally more efficient than enterprise-owned facilities, as these sites typically operate with newer equipment and are more highly utilized, which helps equipment run more efficiently. In addition, the business model incentivizes providers to be more efficient to keep costs down. Moreover, digital services such as video conferencing that are run out of such facilities have the potential to reduce emissions in other sectors, by, for example, reducing business travel and commuting.

Still, to make a stronger case for sustainability, datacenter operators regularly fund renewable energy generation projects through corporate power-purchase agreements (CPPAs), with many working their way toward having 100% renewable coverage through such mechanisms. However, these CPPAs are not available everywhere, particularly across Asia.

In addition to energy, water is also a contentious area, though it tends to be a local matter rather than global. Modern datacenters use very little water directly; however, the perceived social and environmental value of water overrides purely economic and technical efficiency considerations. We expect this trend to gain strength as the effects of climate change become more pronounced. In response, technology vendors and datacenter operators have already designed facilities that use much less, or in some instances zero, water.

As regulations increase, it makes even more sense for enterprises to leverage leased datacenter facilities rather than run their own datacenters, as this shifts the compliance requirements to the datacenter provider, while ultimately bettering the enterprise's own carbon profile. Currently, the major consumers of datacenter space tend to be large hyperscale cloud providers, web-scale companies or multinational enterprises, many of which now have corporate ESG policies in place, and datacenter capacity can be a major contributor to the firm's overall carbon footprint. Thus, government policy initiatives can be supportive of an enterprise's own ESG initiatives.

## Trend 2: Low-Carbon Technologies for Backup Generation Are Emerging at Datacenters



**Implication:** Intermittency of renewable energy presents several challenges for leased datacenter providers, but hydrogen could be one solution to help the industry reduce its dependence on fossil-fuel-powered grids.

Datacenter providers' ability to use energy from renewable sources is still largely dependent on the public electrical grid and on government approaches to energy policy. In one example, datacenter providers in Singapore have had to be resourceful in their search for renewable energy, since the government has been critical of the industry's large carbon footprint but there have been few renewable power options available through the public grid. In March 2021, solar energy provider Sunseap, which works with Microsoft and Apple's datacenters in Singapore, unveiled a floating solar farm that could produce an estimated six million kilowatt hours of energy per year at 5MW peak installation. Industry participants are also discussing the expansion of datacenters powered by onsite generated hydrogen.

One option is the 'rack-level fuel cell,' which calls for hydrogen fuel cells to be installed in individual racks and supplied by natural gas via a gas line in the facility. This has been explored to replace grid power or to replace the diesel generators currently used at most datacenter sites for backup in case of an interruption in grid power.

Microsoft has experimented with using hydrogen fuel cells at its datacenters with some measure of success. In June 2020, the cloud giant announced that it used hydrogen stored in trucks to feed into a 250kW hydrogen fuel cell powering a row of servers at its datacenter near Salt Lake City, Utah, for 48 consecutive hours. Mark Monroe, principal engineer of the company's Datacenter Advanced Development Group, has also led a trial that used hydrogen fuel cells as backup power in case the main power grid experienced an outage.



Hydrogen can burn without emitting greenhouse gases, making it a possible way for datacenter providers to reduce their carbon footprint. Yet for now, the technology is still in development and is far from economically viable, so it does not appear ready for widespread adoption. Stringent procedures are required to produce hydrogen in a carbon-neutral way, while 'grey hydrogen' – hydrogen produced using a steam-methane system – is the most common approach. However, this process extracts hydrogen from fossil fuel and releases carbon monoxide and carbon dioxide.

Singapore-based Keppel is perhaps one of the first providers in the APAC region to explore using hydrogen at its datacenters. It has teamed up with players including Mitsubishi Heavy Industries, Dutch oil and gas company Royal Vopak and its subsidiaries City Gas and City-OG Gas Energy Services to study the feasibility of a hydrogen-powered trigeneration plant for its datacenters through the steam methane reforming process.

The trigeneration plant is supposed to generate heat, power and cooling to allow the datacenters to reduce reliability on the power grid. The collaboration is expected to benefit Keppel's floating datacenter park, which is under construction offshore in Singapore and could serve as a model for datacenters in other regions as well.

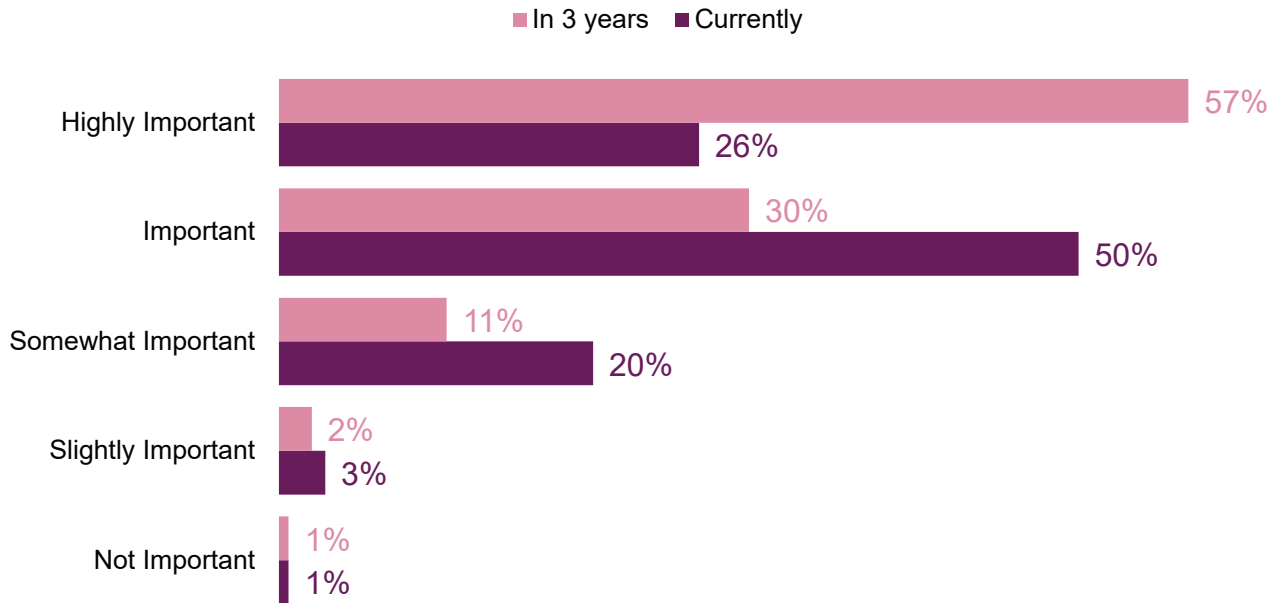
### Trend 3: Sustainability Will Become A Differentiator for Datacenter Providers



**Implication:** The environmental impact of datacenters is a growing concern for customers and local governments. The industry has tended to focus on resiliency and cost, but sustainability is increasingly an area where datacenter providers can differentiate, for example by using advanced technology, sourcing renewable power and evaluating environmental impacts when choosing sites. In the years ahead, enterprises may use environmental footprint as a criterion for evaluating where to put workloads, in addition to more traditional criteria such as cost and performance.

Hyperscale datacenter customers have led the market in securing renewable power and updating datacenter design to improve efficiency and sustainability, in many cases requiring their suppliers to do the same. Smaller customers are also starting to pay much more attention to sustainability, broadening the impact on the industry. According to a global survey of datacenter services providers conducted by 451 Research in 2020, half of the operators say their customers' requirements are a key factor in their investments in sustainability initiatives. The majority of service providers also expect sustainability to become a key competitive differentiator in three years (see Figure 1). This is not a surprise when we consider that the largest enterprises report on their resource footprint as part of their ESG commitments. Nine out of ten of the companies in the S&P 500 Index published a sustainability report in 2019, up from only 20% in 2011, notes the Governance & Accountability Institute.

**Figure 1: Sustainability/Efficiency Are Becoming Ever More Important**



Q. How would you rate the importance of efficiency and sustainability to your organization's competitive differentiation? Currently and in 3 years?

Base: All respondents (n=825)

Source: 451 Research survey for Schneider Electric, June 2020

However, there can be trade-offs when datacenters seek to reduce their use of resources. For example, a datacenter may use large amounts of water to cool facilities in areas where water is scarce, but using less water would require using mechanical air conditioning, which requires more power; if the power generation is in an area where it uses water, total water use may actually rise. Conversely, if the grid runs on renewable energy, perhaps a datacenter operator should use more mechanical cooling to reduce water consumption.

The topic may well return to the desks of consultants and engineers, who will need to make choices based on stricter environmental mandates. Solutions may include direct investments in green power plants, use of energy storage and grid demand response schemes, expanded use of efficient evaporative coolers or direct liquid cooling, reduced reliance on diesel generator backup, more relaxed operating temperatures in the data hall, and better uses of waste datacenter heat, such as for heating local homes. There have also been efforts to quantify resource use by workload and by location, producing dashboards that will allow enterprises to more easily use sustainability as a criterion for determining where to place workloads (comparing, for example, enterprise datacenters with public cloud deployments).

Finally, natural disasters such as fires, floods, hurricanes, tornadoes and ice storms are becoming more common in areas where they were previously considered rare or unlikely. Even when the datacenter is in a relatively safe location during a weather event, the datacenter staff and their families may lose their homes or be unable to reach the facility. Automation may help with some of these issues, as will redundancy that is built into software. But automation requires investment for most operators, and for most of their clients, the datacenter's resiliency is still the main insurance policy against outages. Still, engineering based on historical worst-case climatic conditions may not be enough in the future.

# Information Security

**Channel contributors:** Scott Crawford, Garrett Bekker, Eric Hanselman, Daniel Kennedy, Fernando Montenegro, Aaron Sherrill

From the societal implications of security threats, to the environmental risks arising from the exposure of digital controls to cyberattack, cybersecurity plays a leading role in establishing priorities for ESG. Security concerns continue to grow along with the increasing pervasiveness of technology within all sectors of society. Adversaries of all kinds see opportunity multiplying everywhere – and their motives aren't limited to crime or material gain. Political, strategic and social objectives also come into view, extending the purview of cybersecurity and raising demands for a more comprehensive and systematic approach to security as an aspect of governance, with policy and practice based on credible and objective evidence wherever possible to dispel fear, uncertainty and doubt.

## Trend 1: Measuring Cybersecurity in Business Terms Will Reinforce Its Role in Governance



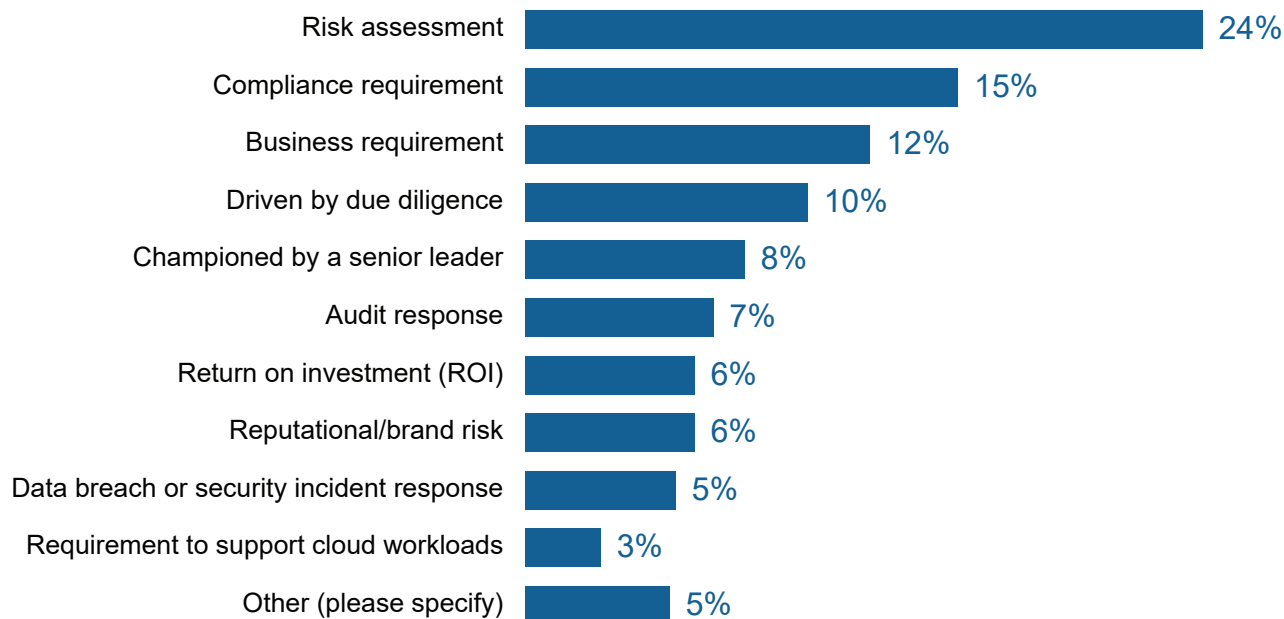
**Implication:** A growing dependence on cybersecurity to assure the sustainability of the digital enterprise has made it a priority for organizations of all kinds. For investors and stakeholders, this means measuring the impact of cybersecurity – and it means doing so not in isolation, but in credible business and financial terms. Still largely a nascent endeavor for many, efforts that gain traction will open the door to increased emphasis on quantifying cyber risk and its management as part of ESG initiatives.

Cybersecurity incidents inevitably impact an organization's bottom line. Investors and stakeholders want to be informed about the factors that contribute to that impact to better understand their potential exposure. This also means that stakeholders expect organizations to invest proactively in identifying and mitigating cyber deficiencies – which affects financial performance. The return on that investment should be improved resilience against material cyberthreats, which should be reflected in measurably reduced exposure and impact. Both the reactive and proactive aspects of cyber risk management make its quantification in relatable strategic terms a priority for corporate governance.

The quantification of cybersecurity is not a new phenomenon. Organizations have long sought to measure factors such as the extent of exposure and efforts to mitigate threats. Progress is being made in areas such as risk-based vulnerability management, which prioritizes the unwieldy challenge of vulnerability remediation based on factors such as actual breach data or evidence of active exploits 'in the wild.' Analyses of cyber incidents such as Verizon Business's Data Breach Investigations Reports provide real-world evidence that can be applied to such efforts.

These represent initiatives that emphasize an evidence-based approach to risk assessment – and risk assessment is the most often reported determinant in the approval of information security projects, according to 451 Research's [Voice of the Enterprise \(VotE\): Information Security, Workloads & Key Projects 2020](#) study.

**Figure 1: Key Determinants for Infosec Project Approval**



Q. For the top information security projects currently being implemented within your organization, what was the key determinant in their approval?

Base: All respondents (n=455)

Source: 451 Research's Voice of the Enterprise: Information Security, Workloads & Key Projects 2020

Each of these measures is only meaningful to the leadership and stakeholders in an organization if it can be expressed in terms of the value of proactive investment and reactive cost – and that most tangibly in financial terms. This, however, is sometimes regarded as the most challenging ‘last mile’ of cyber risk measurement. Can organizations realistically and credibly measure the financial impact of cyberthreats and their mitigation?

Perhaps surprisingly to some, the answer is becoming a more frequent ‘yes.’ Regulatory penalties, of course, provide an often-referenced example, with vehicles such as the General Data Protection Regulation (GDPR) setting a visible bar as high as €20m (approximately US\$24m) or 4% of annual global turnover, whichever is greater. Public companies that sustain a breach, meanwhile, may provide evidence of impact in required financial reporting. On the more proactive side of quantifying financial impact, some technology vendors have gone so far as to offer their customers warranties. WhiteHat Security was among the first to embrace such an approach; others include Cybereason and CrowdStrike.

But there are other sources of insight that have the potential to link specific aspects of security incidents more systematically to their impact on a business. Insurance claims, for example, could provide such linkage, if the insurance industry is able to apply the same evidence-based approach to cyberthreat mitigation as it has, say, to preventive healthcare. One powerful motivation for the insurance industry to become more proactive in this regard may well be an ongoing rash of ransomware incidents that are forcing insurers to reassess their limits of exposure.

These and similar initiatives can be expected to further influence and refine the measurement of cyber risk, and transform it over time into less of a subjective art and more a true and objective practice.

## Trend 2: Cybersecurity Will Play a Greater Part in Mitigating Social Concerns

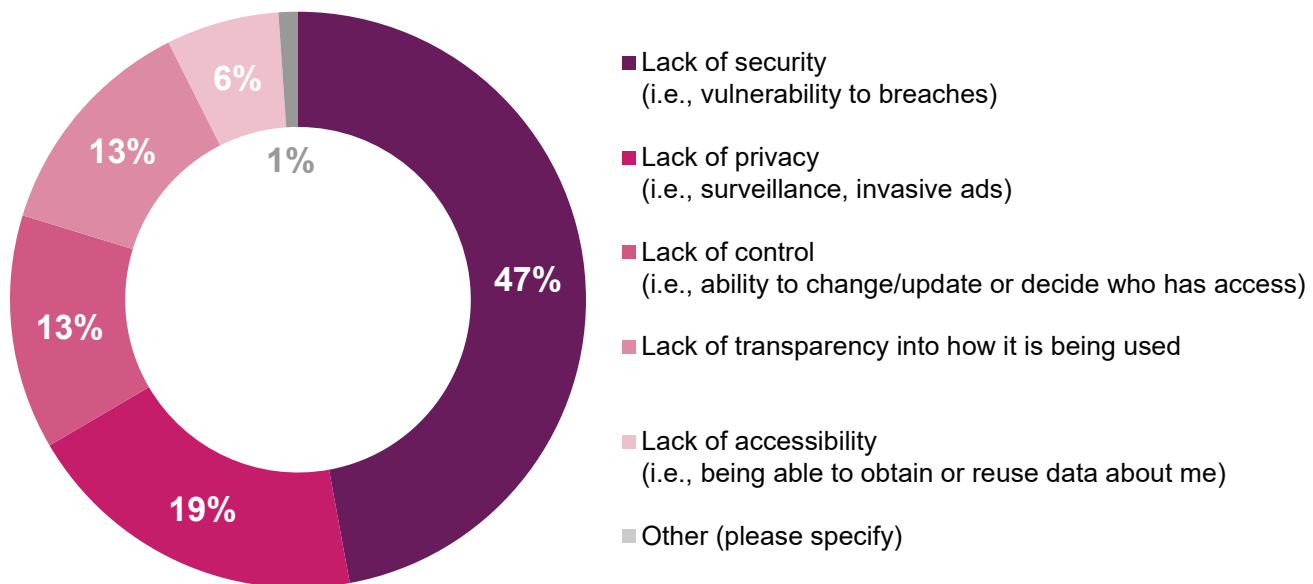
**Implication:** The threat of exposure arising from the widespread and growing collection of personal data and the misuse and distortion of information via social platforms are just two areas in which the role of cybersecurity will become more evident in addressing the social concerns of a digital society. Cyberthreat techniques are often used to achieve goals and hide evidence, which could expand the purview of cybersecurity for mitigating these threats to social integrity.

Digital technology introduces a range of social concerns, from the acceptable use of the ubiquitous collection of personal information, to the use and abuse of social media platforms for reasons both good and bad for society.

People interact extensively with digital technology – but there is a price to be paid for personal interaction, and that’s the potential for exposure of sensitive personal digital assets. Businesses profit from capitalizing on the knowledge of personal habits and preferences. Social media depends directly on personal interactions billions of times each day. The content of social media is generated by the users themselves. Ideally, this enables social media to become a public forum for sharing and disseminating helpful information. But it also introduces threats not only of personal information exploitation, but the distortion of information and perceptions along with it.

People regularly express concerns about the threats to online personal data – but none are as significant to the individual as the fear of cybersecurity incidents, ranked highest by far among respondents to 451 Research’s *VoCUL: Consumer Population Representative Survey, Connected Customer, Trust & Privacy 2020* study (see Figure 2).

**Figure 2: Top Concerns for Use of Personal Data Online**



Q. Which one of the following is your top concern related to the use of your personal data online?

Base: Respondents who are concerned about the privacy of their personal data online (n=1,199)

Source: 451 Research’s Voice of the Connected User Landscape: Consumer Population Representative Survey, Connected Customer, Trust and Privacy 2020

For society, threats extend even further. The rise of social networks has presented a new kind of opportunity for those who seek to destabilize their opponents or weaken them through sowing division. That opportunity lies in the potential to exploit social media for amplifying information and opinion specifically intended to polarize – and for the unscrupulous, it may not matter if that information or opinion is legitimate. For these, the slanting, distortion or outright fabrication of information may also be in view.

Cybersecurity becomes involved not just because these concerns pose a threat to either corporate or public policy, the national interest or the rights of individuals. It's because the tools, techniques and practices of cyberthreat actors are often implicated. Identity theft, account takeover and the creation of fraudulent accounts to further these aims call on such tactics. The discovery of sensitive or privileged information or content to expose, embarrass or discredit may be accomplished through a cyberattack. Content manipulation – including more recent techniques such as 'deep fakes' – may rely on the theft or exfiltration of personal content from compromised sources. Cyberthreat intelligence may be key to obtaining or complementing the insight needed.

For an organization and its ESG priorities, the obligation is to assure not only fair and equal protection against these threats, but to foster an inclusive environment – which may also be reflected in protecting its social presence from cyber exploits. Organizations have direct control over the implementation of security measures for their internal social and collaboration systems. In external environments, their control may be limited and applicable only insofar as it falls within their scope of responsibility.

### Trend 3: As Dependence on 'Smart' Technology and the Intelligent Edge Grows, Cyberthreats Will Pose Wider Environmental and Social Risks



**Implication:** As digital technology increasingly penetrates virtually every aspect of human existence, it also introduces cyber risks. From control over everything from environmental impact and safety in manufacturing, energy, transportation and healthcare, to the implications of pervasive monitoring and tracking, the compromise of this sensitive functionality and data becomes an ever greater target for cyberattacks.

From innovation in virtually every industry to the simpler actions of managing a home, digital technologies are becoming more integrated at almost every level to sense, analyze and act. They capitalize on advances in IT that make their sophisticated functions possible. Increasingly, they also rely on the growing expansion of high-availability connectivity such as 5G networks to expand the performance of connections from computing centers out to an ever more capable edge that may be anywhere – on or in factory floors, farms, vehicles, homes and even individuals.

In industrial settings, these systems do more than multiply the efficiencies of human effort. They also directly control conditions on which the health, safety or security of potentially billions of people may rely. Society's increasing reliance on these capabilities isn't lost on cyber adversaries, who see in this evolution an expansive proliferation of targets. The compromise of utilities or essential services such as logistics in the supply chain could be highly disruptive to society – a fact made starkly evident in the 2021 ransomware attack against Colonial Pipeline – while increased reliance on digital technologies in healthcare could pose a threat to personal safety and security, as well as to highly sensitive healthcare information.

Digital systems also exert increasing control over society's impact on the environment. The compromise of a wide range of systems – such as energy production and transmission, the navigation and control of oceangoing vessels, water and waste treatment facilities and much more – could result in accidents or incidents with devastating consequences for natural resources and whole populations.

Social concerns include the responsible handling of sensitive information, as well as the level of intrusion that may be introduced by technologies that continuously monitor the environment. According to 451 Research's [VotE: Internet of Things, The OT Perspective, Use Cases and Outcomes 2020](#), video surveillance is the most frequent 'smart city' IoT use case reported by public sector respondents. At 41%, it is well ahead of public health tracking at 25%.

One of the more difficult aspects of this reliance is the pervasiveness of such monitoring. On the positive side, the extent of this vigilance can make it more difficult for the malicious to act with impunity. This played a role, for example, in the apprehension and conviction of the perpetrators of the Boston Marathon bombings in 2013, and many other acts of both greater and lesser impact before and since. Tracking has made also it possible for a society to be aware of cases of exposure to outbreaks of a pandemic, which can help to contain its spread.

But this extensive visibility also has the potential to be abused when called upon to target or constrain the freedoms and rights of both individuals and groups. The very availability of this level of data-gathering and -management capabilities and insight can pose problems.

Cybersecurity controls are essential for containing threats and assuring that these capabilities fulfill their intended promise. But without an equivalent level of transparency over the security applied to pervasive digital transformation, controls designed to protect may themselves be exploited to compromise targets or obscure malicious intent. That can be amplified when the 'downstream' reliance of multiple parties is threatened by the compromise of specific digital suppliers with wide adoption – a threat evident in recent incidents affecting thousands of organizations using specific network management tools, VPN providers or email systems, further complicating a clear view toward a more reliable digital future.

# Internet of Things

**Channel contributors:** Christian Renaud, Mark Fontecchio, Eric Hanselman, Ian Hughes, Rich Karpinski, Leika Kawasaki, Jessica Montgomery, Brian O'Rourke, Brian Partridge, Dr. Katy Ring, Jonathan Stern, Johan Vermij

The sensors, connectivity, compute and analytics that comprise the Internet of Things (IoT) are natural partners with the wider ESG movement. From enabling transparency of manufactured goods and supply chains to ensure that they have the least environmental impact to adhering to social and governance policies, IoT shifts the conversation from aspirational goals to concrete, data-supported evidence. Furthermore, IoT and broader digital transformation efforts bring together all parts of an organization, from operations to IT to finance, and demand a holistic approach to providing outcomes instead of point products; this is the same set of stakeholders necessary to enact broad ESG programs.

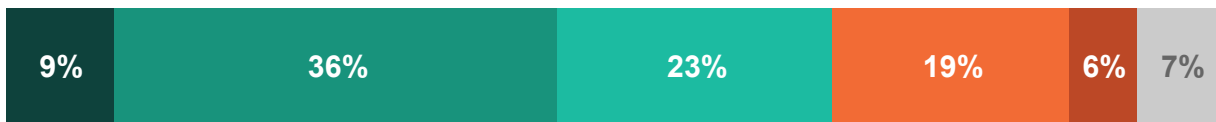
## Trend 1: Digital Twins and Digital Threads Provide Data Transparency for ESG Goals



**Implication:** Digital twins and digital threads provide visibility into components and supply chains to measure, manage and enforce regulations and targets for ESG compliance.

Knowing the current status of machinery and the provenance of its component parts (or manufactured items) is increasingly mandatory for industrial organizations. Sixty-eight percent of manufacturing respondents to 451 Research's Voice of the Enterprise (VotE): Internet of Things, The OT Perspective, Use Cases and Outcomes 2020 survey are partially or fully deploying digital twin or digital thread processes across their operational systems today (see Figure 1). These technologies give organizations 'x-ray vision' into the state of manufacturing processes and equipment, speeding access to cross-plant instrumentation and status, reducing cycle time for designing new processes or installing new equipment, and simulating 'what-if?' scenarios for maintenance, diagnostics and process improvement, and virtual training systems.

**Figure 1: Manufacturing Organization Use Cases for Digital Twins**



- Yes, processes designed digitally, deployed and operated with a live synchronized digital twin.
- Yes, capturing machine data and maintaining an up-to-date virtual model of the current operational state.
- Yes, capturing a partial virtual model of the current state of the main indicators.
- No, machine instrumentation is accessed on request as needed.
- No, but data recorded in a historian.
- None of the above

Q. Does your organization operate a digital twin and digital thread process across your operational systems today?

Base: Manufacturing respondents (n=124)

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



An additional benefit to these technologies is temporal. Where digital twins enable visibility into factories, processes and machinery, digital threads add a fourth dimension, time. Digital threads can look back at the past behavior and performance of the asset as well as its component parts. This is particularly relevant in all three areas of ESG as the provenance of manufactured goods, as well as the provenance of the component parts that comprise the goods, can be ascertained. Nowhere is this more relevant than process manufacturing, where ingredients used in the manufacturing of a packaged food can be traced back to their origin in the event of a recall needed due to corruption of the source ingredients in processing or transport.

Environmentally, this transparency and visibility enables stakeholders to calculate the upstream and downstream emissions of the manufacturing process, good or components. One example of this is the cobalt used in modern electric vehicle batteries. A majority of cobalt hydroxide used in electric vehicle batteries is sourced in the Democratic Republic of Congo (DRC), shipped from South Africa, and refined in China. It is then incorporated into battery cells in China or transported to countries where battery cells are manufactured closer to the point of auto production. This causes environmental impact at the point of cobalt extraction in the DRC, emissions from rail to South Africa, shipping to China, the refining process, and emissions tied to the manufacturing the final battery cell.

Digital twins and threads can also shed light into the social aspect of how organizations deliver value to customers. By asserting the provenance of component parts of both the production equipment and any manufactured goods, organizations can align their supply chain to minimize downstream safety and geopolitical risks. This could be visibility and control of the storage, transport and cleaning of oats for gluten-free cereals or the location and disposition (prone, upright) of workers in dangerous environments such as mines and chemical refineries in the event of planned or unplanned detonations. This also provides a documentary record of the source of each component or ingredient used in the manufacture of a finished good, which companies can regularly review against safety, labor equity, and governmental alignment with corporate goals.

This practice also helps ensure that organizations and suppliers have robust corporate governance structures in place. [S&P Global assesses](#) companies' governance performance using four primary factors: structure and oversight, code and values, transparency and reporting, and cyber risk and systems. Digital threads provide insight into the latter two factors specifically in laying bare the supply chain and processes within suppliers, via live or reported metrics, as well as enabling the assessment of cyber risk based on controls and processes in place throughout the multitude of vendors in the supply chain. Using company 'scorecards' of the downstream suppliers within a digital thread of a machine or finished good, companies can also develop a blended score of the gender diversity and equity of its suppliers.

Having visibility into the provenance of raw materials and parts used in the manufacture of finished goods will shorten recall windows, help identify critical flaws in the manufacturing process before issues arise, optimize supply chains to reduce environmental impact, address social challenges in worker safety and labor practices, and provide visibility into transparency and reporting as well as cyber risk and systems. In the aggregate, the benefits of digital twins and digital threads will provide a powerful new tool for organizations to leverage in broader ESG initiatives.

## Trend 2: IoT Enables Precise Location and Status Data, Resulting in Lower Emissions and Environmental Harm



**Implication:** Technologies including global positioning system/global navigation satellite system (GPS/GNSS), video analytics, AI and edge computing combine in use cases from fleet telematics to precision agriculture, yielding far greater efficiency and reducing both emissions and waste.

Telematics, or the collection of operational data from vehicles (cars, trucks, tractors), is a decades-old technology that has undergone incremental improvements at regular intervals. Modern telematics includes technologies such as active advanced driver assistance systems in passenger cars and commercial trucks; precision agriculture that uses high-resolution location data to drive large tractors and implements in straight lines to avoid under/over-planting and -spraying; and critical status data (telemetry) of vehicle components that form the foundation for predictive maintenance, avoiding unscheduled downtime.

While these technologies may seem mundane, the ramifications from access to this data is anything but. Knowing the location of consumer or commercial vehicles enables navigation systems to route around traffic problems (or in some cases, balance traffic load across roads to avoid the creation of problems) and determine optimal routes for commercial vehicles that reduce vehicle emissions and possible spoilage of transported cargo. In agriculture, this results in tractors that drive straighter and that can plant, apply herbicide and harvest crops spaced at optimal intervals with no overlap or gaps, resulting in more food for the planet's growing population, with far less use of fertilizers and herbicides.

In all of these industries, the information gleaned from a network of sensors on the vehicle are being fed into machine learning models that can anticipate failures before they occur, triggering predictive maintenance of the vehicles. The alternative is downtime, causing safety issues for consumers and commercial drivers, inventory spoilage, impacts on hours-of-service regulated maximum driving times, and missed planting or harvesting windows in agriculture.

## Trend 3: Digital Transformation and IoT Projects Engage Stakeholders From Across Business Functions



**Implication:** IoT projects mandate collaboration between operational groups (factory, fleet, etc.) and IT, often with finance and executive participation in broader digital transformation efforts. ESG objectives can be included as explicit goals of new projects buttressed with broad organizational support, ensuring the ability to follow through.

Digital transformation efforts enlist stakeholders from across and 'up' the organizational chart (see Figure 2), which is a key element of success for any broad-reaching effort such as implementing ESG metrics. These metrics, according to respondents to 451 Research's *VotE: IoT, The OT Perspective, Use Cases and Outcomes 2020*, include ESG-aligned objectives such as assisting workers in performing mission-critical tasks, improving worker safety, leveraging digital twins/threads, and reducing energy emissions and expenses from real estate/buildings.

**Figure 2: Digital Transformation Strategy Influencers**



Q. Which of the following groups are involved in or influence your organization's digital transformation strategy? (Check all that apply)

Base: All respondents (n=451)

Source: 451 Research's Voice of the Customer: Macroeconomic Outlook, Corporate IT Spending, Digital Transformation 2020

It is the executive visibility of digital transformation and IoT projects that make them ideal vehicles for implementing ESG goals. When transforming a business, a key pillar in the new technologies and processes is the equitability of the organization put in place above them to achieve company ESG objectives. This is in addition to ensuring the safety of all workers, having measurable governance of how the organization builds its products or services, and minimizing environmental emissions and damage to the greatest extent possible. The engagement of a wide array of stakeholders from across the organization will improve the likelihood for the creation of realistic, measurable goals, as well as the likelihood for follow-through of plans and accountability to accomplish ESG objectives.

# Workforce Productivity & Collaboration

**Channel contributors:** Chris Marsh, Raul Castanon-Martinez, Conner Forrest, Rosanna Jimenez, Nick Patience

A new social contract is slowly developing, with employers under increasing pressure to be more socially responsible to their employees and not just driven by profits. The digital workplace, with a large estate of productivity, collaboration and engagement technologies, will play a critical role in mediating these priorities. Business and technology leaders will need to be much more thoughtful as to how they expect those technologies to drive a range of business goals.

This is both a cultural and technical shift for businesses and their technology providers. Culturally, the frame of reference for what it means to be socially responsible toward employees is widening, and the technology supply side is responding. Workforce tooling has historically focused more on productivity and compliance, but its impact on organizational governance – especially around risk management, privacy protection and compliance reporting – and its impact on human capital management and employee engagement are increasingly recognized.

That technology increasingly matters is exemplified by our [Voice of the Enterprise \(VotE\): Workforce Productivity & Collaboration \(WPC\), Employee Engagement 2020](#) survey, which shows:

- Thirty-five percent of employees would accept a new job if the only way it differed from their current job was the better availability of devices, applications and other productivity tools.
- After better compensation and benefits, having a more enjoyable day-to-day experience where they feel more productive and engaged around their work is the biggest reason (mentioned by 28%) why employees would leave their current employer.

An important impact of the digitizing workplace will be on how ESG strategies are conceived, designed and implemented. Businesses can increasingly look to their workplace technologies to balance their duty to ‘do good’ with the imperative to be financially performant, and in so doing they will have more tools at their disposal to make their ESG commitments more and more meaningful over time.

## Trend 1: New Operational Cultures Will Embed Social Responsibility in Business Resilience

**Implication:** Businesses are beginning to invest in the idea of an operational culture – as distinct from values-based ways of thinking about company culture – to better balance supporting their employees while being resilient to social and economic disruptions. To date this kind of thinking has been lacking, with businesses divided by their different organizational silos implementing policies that are aimed at supporting employees but aren't well coupled with business performance goals. Technology will play a huge role in giving shape to this new thinking around operational cultures, especially as more businesses support a hybrid workforce model.

Globalization, digital transformation, social justice movements and black swan events like the coronavirus pandemic provide a challenging environment for businesses. A growing number are realizing that resilience needs to be based on a whole organization approach that links strategies around human capital management; diversity, equity and inclusion; and employee experience more specifically to business goals including risk management, workforce productivity and financial performance. Social responsibility is increasingly being understood not just as 'doing good' but as a key enabler for business resilience. This explains why a recent custom multinational survey of technology leaders conducted by 451 Research shows 53% now consider improving their workforce experience as a digital transformation priority.

There is, however, a lack of language to think through how to make this happen because many businesses are still typically organized around divisional and technology silos that relegate 'culture' to either high-level, values-based mission statements, or very tactical descriptions of how teams operate. Without this more unified view of an operational culture, attempts to better support employees and invest in good governance risk being well-meaning but ineffective.

Fortunately, a picture is crystalizing around how to combine employee engagement, good governance and business resilience – one that is heavily informed by 20 years of digital transformation experience:

- **Driving employee productivity does not always drive engagement, but more engaged employees are almost always more productive.** From that often flow other benefits beyond productivity, such as prolonged tenure and accelerated career progress. A more mature view of engagement is emerging, going beyond things like flexible work policies, compensation and wellness to include the quality of the day-to-day experience in getting work done, transparency around and inclusion in strategy creation, and opportunities to learn new skills and be mobile across roles to progress in one's career.
- **At a strategic level, digitally progressive businesses have realized that the pursuit of more operational agility is ultimately at the root of most of their digital transformation initiatives.** That agility increasingly flows from workforce technologies that give employees more autonomy to do more sophisticated things in how they design and execute on their work and manage their wider workplace experience. As technologies have matured, it has become increasingly possible to align that empowerment at the workforce edge back to strategic goals, governance, compliance and security requirements.
- **The sweet spot at the nexus of that agility, autonomy and alignment will provide much of the foundation for the discussion around operational culture.** More tactically, the continuing consumerization of enterprise technology is driving workforce tooling to pull from modern digital consumer experiences in providing more context, control and convenience for end users.

Being responsible to one's employees will increasingly mean activating these characteristics in an operational culture. This wider frame of reference will help to more closely contextualize socially responsible policies within business performance goals. Therefore, having a more specific conversation around their operational culture will be important for businesses' ESG strategies.

## Trend 2: A More Joined-Up People Management Stack Will Support Good Governance in Disruptive Times

**Implication:** Businesses face an ever more disruptive external environment replete with complexities that will require new risk and crisis management strategies. As such, there needs to be a tighter link between the imperatives of being more operationally agile and better managing human capital, which is often the highest-cost and most valuable asset. Good governance will increasingly be predicated on having the systems, internal controls and culture to more nimbly appraise, develop, manage and plan around a business' skills base to better respond to that dynamic risk environment.

While much of the business impact from the pandemic was initially experienced as disruptions to customer demand, supply chains and workforce layoffs, it is coming to be felt more strongly in the challenges businesses face in surviving and competing in less predictable competitive environments. Businesses need to build in as much resilience and elasticity as possible within their workforce, which is gradually leading to a more joined-up people management stack – the improved ability for businesses to appraise, develop, manage and plan around their skills base. We expect to see a range of different technology approaches implemented to support corporate governance around human capital:

- **Advanced scenario modeling will become table-stakes. Businesses need to more quickly understand risks, reorient their strategic direction and allocate resources accordingly.** This is increasing the demand for agile scenario modeling capabilities in planning software contextualized across business functions. Power users will expect stronger capabilities for creating and managing contingency plans for a variety of situations. Business leaders across departmental functions will be expected to be more specifically involved in continuous planning initiatives.
- **Resource management will be democratized.** Resource management will also pass further down the chain, becoming more embedded within a wider range of tooling beyond project and workforce management and ERP tools. Responsively managing shifting dependencies between people and their workloads will become important not only for operational agility but also for more democratized use cases such as preventing burnout.
- **More businesses will look to upskill employees and apply those skills across different work initiatives.** Businesses will look for tools to understand skills proficiencies and appraise them in the context of multiple workloads, mapping them to specific business needs as required. Our [VotE: WPC, Employee Lifecycle & HR 2021](#) survey shows that 56% of team managers see more dynamically matching their teams' skills to their business goals as the best way to improve how they manage their skills base. The same survey shows that 40% of HR professionals see learning and development as their biggest area for investment across all of the department's functions over the next year (see Figure 1).
- **Workforce management will be regularized.** Capabilities such as work scheduling and schedule forecasting, predictive attrition analysis and productivity tracking will bleed over from contractor and part-timer management into the main workforce cohort. It's an area already under scrutiny – top among the demands for capabilities in workforce management platforms (mentioned by 46% of HR professionals in the Employee Lifecycle & HR survey) is having visibility across their entire workforce to be able to manage in-office, frontline, field worker and remote employees alike.
- **Employee engagement 2.0 will gather speed.** Given the strain that employers and employees are under (71% already reported finding their jobs stressful pre-pandemic), we anticipate acceleration into the next phase of engagement strategies. Version 2.0 will be characterized by a shift from just measuring sentiment through one-to-many pulse surveys and outward recognition of good work well done, to more concerted efforts at culture-building, more participative decision-making, and a stronger focus on determining specific engagement drivers for productivity.

**Figure 1: Businesses See Opportunities To Focus on Employee Upskilling**



Q. Which of the following changes, if any, would most improve the way you manage employee skills on your team? Please select all that apply. Base: Respondents who are team managers (n=72)

Q. Which HR functions is your organization planning to make the biggest investments in over the next 12 months? Please select all that apply. Base: All HR respondents (n=88)

Source: 451 Research's Voice of the Enterprise: Workforce Productivity & Collaboration, Employee Lifecycle and HR 2021

### Trend 3: The Evolution of the Human Resources Department Bodes Well for ESG Strategies



**Implication:** Human resources departments will play an important role in helping shape ESG strategies that are both socially responsible and impactful to organizational performance. Our Vote: WPC: Employee Lifecycle & HR 2021 survey shows the same level of focus among HR professionals in improving employee productivity and collaboration as in formulating programs for employee wellness and mental health, as HR professionals reset their priorities coming out of the pandemic.

The human resources function is in the midst of a transformation because workforce needs are changing and new HR technologies are coming into the hands of practitioners at a rapid clip. In some of the more forward-thinking organizations, HR is getting a bigger seat at the table and – in certain instances – is being given an opportunity to take a growing role in the mission statements, strategy and planning of their businesses. HR's evolution from back-office function to more of an innovation leader will be supported by the following trends:

- **HR involvement is needed in a growing number of business priorities and will facilitate significant cross-functional collaboration in the coming years.** This may include collaborating with IT around the tools underpinning an enjoyable and effective daily workplace experience; with finance, legal and hiring managers to support more dynamic ways of managing a multi-generational workforce; or with marketers bolstering candidate recruitment efforts in the war for talent.

- **A growing number of planning software vendors are also looking to support the HR function as businesses look more strategically at headcount and workforce planning.** This has been catalyzed in part by hiring freezes and worker furloughs during the COVID-19 pandemic, and by ongoing discussions about returning to the workplace. It also feeds into goals such as dynamic talent and skills management and productivity planning. Planning platform vendors will find a willing audience in HR professionals, 45% of whom indicate an increasing need for data literacy in their skill set, according to our Employee Lifecycle & HR survey. Modern planning will be built on a close collaboration between strategic planners and HR.
- **Progressive ESG strategies will also reflect that the frame of reference for how to ensure employees feel engaged is changing, especially in light of the disruptions of 2020.** The agenda needs to expand beyond traditional concerns around the physical safety of the workplace environment to issues of mental health. There will likely be more focus on policies that support more flexible working styles, paid sick leave, dependent care and more specific career initiatives supporting the development of employees.



# Methodology

This report was compiled by analysts from across 451 Research's different research practices. Reports such as this one represent a holistic perspective on key emerging markets in the enterprise IT space. These markets evolve quickly, though, so 451 Research offers additional services that provide critical marketplace updates. These updated reports and perspectives are presented on a daily basis via the company's core intelligence service, 451 Research Market Insight. Forward-looking M&A analysis and perspectives on strategic acquisitions and the liquidity environment for technology companies are also updated regularly via Market Insight, which is backed by the industry-leading 451 Research M&A KnowledgeBase.

Emerging technologies and markets are covered in 451 Research channels including Applied Infrastructure & DevOps; Cloud & Managed Services Transformation; Cloud Native; Customer Experience & Commerce; Data, AI & Analytics; Datacenter Services & Infrastructure; Information Security; Internet of Things; and Workforce Productivity & Collaboration.

Beyond that, 451 Research has a robust set of quantitative insights covered in products such as VotE, Voice of the Connected User Landscape, Voice of the Service Provider, Cloud Price Index, Market Monitor, the M&A KnowledgeBase and the Datacenter KnowledgeBase.

All of these 451 Research services, which are accessible via the web, provide critical and timely analysis specifically focused on the business of enterprise IT innovation.

For more information about 451 Research, please go to: [www.451research.com](http://www.451research.com).

This report cites data from the following 451 Research data products:

- **Industrial IoT Market Monitor, March 2021** – This proprietary forecast is based on a bottom-up analysis of more than 1,000 endpoint types across 12 verticals and over 300 use cases at a country and regional level with forecasts of revenue, connected devices and data generation. It includes growth expectations through 2025.
- **Voice of the Connected User Landscape: Connected Customer, Trust & Privacy 2020** – This web-based survey was from October 5 to October 23, 2020 among approximately 5,000 US online consumers who are 18 years of age or older.
- **Voice of the Connected User Landscape: Tablets & PCs, Purchase Drivers & Motivators 2020** – This web-based survey was fielded in Q4 2020 in two parts. The first was fielded to approximately 1,000 members of 451 Research's Leading Indicator panel of business and tech professionals and early adopter consumers primarily based in North America. The second included a population-representative sample of approximately 2,500 US online consumers who are 18 years of age or older.
- **Voice of the Customer: Macroeconomic Outlook, Business Trends, Automation and Technological Change 2020** – This web-based survey was fielded from August 17 to September 14, 2020 among a population-representative sample of approximately 900 primarily North American respondents. The survey is largely representative of small and medium-sized businesses.
- **Voice of the Customer: Macroeconomic Outlook, Corporate IT Spending, Digital Transformation 2020** – This web-based survey was fielded in November and December 2020 among a population-representative sample of approximately 500 primarily North American respondents.
- **Voice of the Enterprise: AI & Machine Learning, Infrastructure 2020** – This web-based survey was fielded from May 4 to May 20, 2020 among approximately 700 IT end-user decision-makers worldwide.

- **Voice of the Enterprise: AI & Machine Learning, Use Cases 2021** – This web-based survey was fielded in October 2020 among approximately 1,000 IT end-user decision-makers worldwide.
- **Voice of the Enterprise: Customer Experience & Commerce, Digital Maturity 2020** – This web-based survey was fielded in October 2020 among approximately 500 IT and line-of-business decision-makers worldwide.
- **Voice of the Enterprise: Customer Experience & Commerce, Merchant Study 2020** – This web-based survey was fielded in March and April 2020 among approximately 260 IT and line-of-business decision-makers worldwide.
- **Voice of the Enterprise: Customer Experience & Commerce, Organizational Dynamics and Budgets 2021** – This web-based survey was fielded in January 2021 among approximately 7000 IT and line-of-business decision-makers worldwide.
- **Voice of the Enterprise: Customer Experience & Commerce, Vendor Evaluations 2020** – This web-based survey was fielded in from July through September 2020 among approximately 1,570 customer experience technology decision-makers and influencers primarily based in North America.
- **Voice of the Enterprise: Data & Analytics, Data Management & Analytics 2020** – This web-based survey was fielded from August 20 to October 19, 2020 among approximately 481 IT and line-of-business decision-makers worldwide.
- **Voice of the Enterprise: DevOps, Organizational Dynamics 2020** – This web-based survey was fielded from August 26 to September 16, 2020 among approximately 551 IT decision-makers and technology practitioners primarily based in North America.
- **Voice of the Enterprise: Digital Pulse, Budgets & Outlook 2021** – This web-based survey was fielded from September 15 to November 18, 2020 among approximately 507 IT and line-of-business decision-makers worldwide.
- **Voice of the Enterprise: Digital Pulse, Coronavirus Flash Survey June 2020** – This event-driven, fast-turnaround web-based survey was designed to measure the impact of the COVID-19 outbreak on businesses. It was fielded from May 26 to June 11, 2020, and represents approximately 575 completes from pre-qualified IT end-user decision-makers primarily based in North America.
- **Voice of the Enterprise: Digital Pulse, Diversity & Inclusion 2021** – This web-based survey was fielded from February 25 to April 3, 2021 among approximately 490 IT and line-of-business decision-makers worldwide.
- **Voice of the Enterprise: Digital Pulse, Vendor Evaluations 2020** – This web-based survey was fielded from June 23 to August 10, 2020 among approximately 536 IT and line-of-business decision-makers worldwide.
- **Voice of the Enterprise: Hyperconverged Infrastructure, Technology & Platform Innovation 2020** – This web-based survey was fielded from October 8 to December 2, 2020 among approximately 412 IT end-user decision-makers worldwide.
- **Voice of the Enterprise: Information Security, Workloads & Key Projects 2020** – This web-based survey was fielded during March and April 2020 among approximately 500 IT decision-makers and technology practitioners primarily based in North America.
- **Voice of the Enterprise: IoT, The OT Perspective, Use Cases and Outcomes 2020** – This web-based survey was fielded during the months of June and July 2020 among approximately 600 operational technology decision-makers.
- **Voice of the Enterprise: Workforce Productivity & Collaboration, Employee Lifecycle & HR 2021** – This web-based survey was fielded in March 2021 among approximately 250 IT end-user decision-makers worldwide.
- **Voice of the Enterprise: Workforce Productivity & Collaboration, Employee Engagement 2020** – This web-based survey was fielded in October and November 2020 among approximately 1,000 IT and line-of-business decision-makers, managerial and non-managerial employees.

- **S&P Global Mobile 5G Commercial Service Launches and Trials, September 2020** – This research shows completed 5G commercial service launches as of September 2020. It also includes spectrum and vendor partner data for 5G trials worldwide.
- **S&P Global/AARP Survey, Q3 2020** – This survey was fielded from August 20 through September 8, 2020 among 1,573 individuals who work for a firm with more than 1,000 employees. The research utilized gender and equality data from Equileap, which covers nearly 1,400 U.S. publicly-listed companies across 11 sectors, and data from the SAM Corporate Sustainability Assessment, an annual evaluation of more than 7,300 companies' sustainability practices across the globe issued by S&P Global, to measure correlations between certain policies and female representation in the workforce and senior management. The research also relies heavily on interviews of executives across corporate America about the benefits they have received and utilized, and their experiences in the workforce.

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