



Digital technology: The backbone of a net-zero emissions future



Preface

“Digital technology: The backbone of a net-zero emissions future” is an MIT Technology Review Insights report sponsored by Shell. To produce this report, in October and November 2022, MIT Technology Review Insights conducted a global survey of 350 C-suite executives. We also interviewed nine industry leaders. Survey respondents are evenly distributed among North America, Europe, and Asia-Pacific. Eight industry sectors were represented. Harry Langer was the author of the report, Michelle Brosnahan was the editor, and Nicola Crepaldi was the publisher. The research is editorially independent, and the views expressed are those of MIT Technology Review Insights.

We would like to thank the following executives for providing their time and insights:

Manju George, Head of Strategy, Platform on Digital Economy, World Economic Forum

Stephane Germain, President, GHGSat

Scott Guthrie, Executive Vice President, Microsoft

Stephanie Jamison, Global Energy and Materials Lead, Accenture

Dan Jeavons, Vice President of Computational Science and Digital Innovation, Shell

Peter Maier, Senior Vice President, Strategic Customer Engagements, Office of the CEO, SAP

Raj Narayanan, Business Head and Chief Manufacturing Officer, UltraTech Cement

Hendrik Sämisch, Founder and Chief Executive Officer, Next Kraftwerke

Satyanarayanan Seshadri, Associate Professor of Applied Mechanics, Indian Institute of Technology, Madras

Foreword

I am deeply convinced that, in a net-zero emissions world, digital technologies and solutions will be the backbone of energy systems. The future of energy is decarbonized, decentralized, and digital.

This report is very timely as we progress in this transformative decade for our industry. Digitalization is already transforming the energy industry, by improving efficiency and safety as well as facilitating the use of renewable energy. Shell's R&D and product deployment shows that digitalization is helping to drive the energy transition in three ways:

1. Helping to make existing operations more efficient and improving mechanisms to monitor and track emissions.
2. Enabling a more rapid redesign of the energy systems of the future with an operating system for more complex, decentralized, and diverse energy systems.
3. Developing new business models with economic incentives to help accelerate the transition to low-carbon energy sources.

The findings of the survey illustrate how the energy transition is happening at different speeds in different places. Sectors, and actors within them, will favor different decarbonization levers. While digitalization is one of the fastest, and arguably one of the cheapest, levers to reduce emissions, it is not everyone's obvious choice to achieve decarbonization goals. This research also shows strong commitment from the energy sector to leveraging digital technologies in support of decarbonization ambitions, but it's clear that executives in other sectors are not yet convinced.

Other findings in the report reinforce my conviction that energy transition is a team sport, and that we need to find ways to partner with customers and suppliers to make the case for digital technology to be at the center of driving decarbonization. This will require new levels of open innovation and collaboration with unusual partners. At Shell, we also believe that it will take the development of open-source platforms and common data standards to accelerate innovation and make it easier to share data and code across organizational boundaries. But not every sector is yet convinced. As digital and sustainability leaders, I strongly believe we must work together to shift that mindset. Otherwise, we will miss out on a key lever to accelerate the energy transition.

The research is clear. Leadership's support is key to any successful digital transformation. But that is not enough. The report's conclusion that a digital culture is needed to understand and address the challenges of decarbonization resonates with me. The true value of digital technology is in the changes to people and processes enabling organizations to rethink traditional ways of working and to make better decisions based on new data-driven insights. Creating buy-in and ownership to embed it in within an organization is hard work and requires steadfast commitment.

As you read this report, I hope you, too, will be convinced of the important role digital technology and successful digital transformations play in the transition to a net-zero emissions future. To read more, visit www.shell.com/digitalisation. Thank you for your interest. We look forward to partnering with you on this journey.



Dan Jeavons

Vice President of Computational Science and Digital Innovation, Shell

CONTENTS

01 Executive summary	5
About the survey	5
02 Increasing carbon efficiency in industry	7
Optimism about digitalization for decarbonization varies.....	7
Energy stands out as a digitalization leader	10
Different industries set different priorities.....	10
Cloud enables transformation and AI	11
03 Upstream, downstream, and the importance of partnering	14
Digitalization benefits are bigger than decarbonization.....	14
Expectations for open standards vary	15
The pros and cons of distributed energy.....	15
Broader and deeper partnerships	17
04 Forming digital coalitions to overcome challenges	18
CEOs can drive transitions	18
Cybersecurity worries are slowing progress.....	19
Calls for regulation and innovation ecosystems	20
05 Conclusion	21

01

Executive summary

The urgency of the global transition to a net-zero economy, focused on solutions that enable the reduction of greenhouse gas emissions, cannot be overstated. As both the engine of global economic growth and substantial emissions generator, industry has a unique responsibility and opportunity to lead this process. And while the energy and petrochemicals sectors have understandably been a central focus of these efforts, decarbonization is essential across all industries.

Digital technologies will be key to the net-zero transition. They enable decarbonization with their ability to process more data more effectively, identify problems faster, and test solutions virtually. Energy-intensive systems will increasingly find efficiency gains from digital and Web3 technologies such as cloud and edge computing, artificial intelligence (AI) and machine learning (ML), internet of things (IoT) sensors, and blockchain technology.

Data is emerging on the impact of digital technologies on greenhouse gas (GHG) emissions, and their importance is clear. The World Economic Forum (WEF) and Accenture say digital technologies can help the energy, materials, and mobility industries reduce emissions by 4% to 10% by 2030.¹ PwC calculates that AI alone can reduce global GHG emissions by 4% by 2030,² while Capgemini reports that the climate potential of AI puts the figure at 16% across multiple sectors.³

Despite these technologies' proven impacts, however, organizations have insufficient urgency around their adoption to accelerate decarbonization and emissions reduction goals. Across industry, many leaders leverage partners to support digital transformation, while energy transition remains a secondary objective. Digital and sustainability leaders are taking a surprisingly conservative approach to technology that fails to address current problems. As justification, they cite immaturity of existing solutions, a need for further study or customization, and challenges ranging from intermittent renewable energy supplies to lack of trust in existing carbon trading schemes.

About the survey

The survey that is the basis of this report was conducted by MIT Technology Review Insights during October and November 2022. All 350 respondents are C-level executives in large organizations, including chief technology officers, chief information officers, chief sustainability officers, chief digital officers, chief operating officers, and chief data officers. Geographically, North America accounts for 31% of the respondents, with the rest distributed globally. About half (51%) of the companies surveyed had revenue between \$1 billion to \$10 billion. Companies with revenue more than \$1 billion make up 31% of respondents. The eight industry sectors represented include energy, metals and mining, industrial manufacturing, construction, technology industry, transport, petrochemical manufacturing, and retail.

MIT Technology Review Insights conducted a global survey to examine industry leaders' use of, plans for, and preparedness to adopt digital technologies to reach decarbonization targets. The survey addressed 350 C-level leaders at large global companies in eight major sectors, to gather their perceptions about these solutions. Insights were also gathered from in-depth discussions with nine subject matter experts.

The following are the key research findings:

• **Digitalization is the backbone that will support energy transition.** Despite differences across industries (and across regions), digital technologies are considered important (rated from 1 to 10, where 10 is most important) for optimizing efficiency and reducing energy and waste (scoring 6.8 overall); designing and optimizing carbon sequestration technologies (6.7); making sustainability data accessible, verifiable, and transparent (6.2); monitoring GHG sinks (6.6); and designing and optimizing low carbon footprint energy systems (5.8).

• **For most industries, the main decarbonization lever is a circular economy.** A majority (54%) of participants from all industries (except for petrochemical manufacturing) cite a circular economy⁴ as their dominant environmental sustainability goal. A circular economy minimizes waste with reduced consumption, increased efficiency, and resource and energy recapture. The second most highly rated sustainability goal is to improve access to clean energy (41%), and third, to improve energy efficiency (40%).

• **Partnership with technology experts is how industry innovates with digital solutions.** The most cited approach to adopting new digital technology is through vendor partnerships (31%). Executives are less likely, however, to emphasize the importance of open standards and data sharing across the supply chain to accelerate digital technology deployment (especially in energy, metals and mining, construction, and petrochemical manufacturing), with only 16% identifying it as the top enabler. Yet, experts say an embrace of open standards and data sharing – essential to AI and ML's ability to conquer complexity – to streamline the supply chain is “inevitable” to meeting decarbonization goals.

• **Attitudes toward tech adoption and innovation vary by sector and region.** Although cybersecurity is considered the biggest external obstacle to digital transformation overall (58%), construction companies are much more apprehensive (76%), while metals and mining companies are less concerned (47%). Overall, 11% of respondents aim to experiment with digital technology early on, but some sectors are less enthused: only 4% in metals and mining, 5% in petrochemical manufacturing, and 6% in industrial manufacturing. Buy-in and a willingness to learn is essential for cooperation across departments and organizations.

• **A digital culture is needed to understand and address the challenges of decarbonization.** The response to new technology solutions is embedded in culture, but the second most common way companies try new technologies is by simply waiting for them to mature (24%). Only one in four respondents want to adopt a digital innovation culture based on knowledge sharing and a learning mindset (25%). Technology roadmaps (19%) and senior leadership (17%) have similar, lesser influence. The success of adopting digital technology depends not just on the availability of data, but on systems and personnel. It falls to leadership to build digital coalitions of internal and external stakeholders, to encourage willingness to digitally transform, and explain the importance of integrating digital technologies.



02 Increasing carbon efficiency in industry

A net-zero emissions future hinges on digital technology. IoT devices, cloud, and big data analytics have proven their ability to increase efficiency and reduce emissions for factories, buildings, and other energy-intensive assets. Digital twins, AI, and ML solutions can reduce carbon footprints. Blockchain has the potential to develop trustworthy and transparent carbon markets. However, the International Energy Agency (IEA) says technology innovation at large is lagging: Almost half the technologies needed by 2050 are only in prototype stage.⁵ Progress is slowing.

In late 2022, MIT Technology Review Insights and Shell conducted a global survey of executives to measure

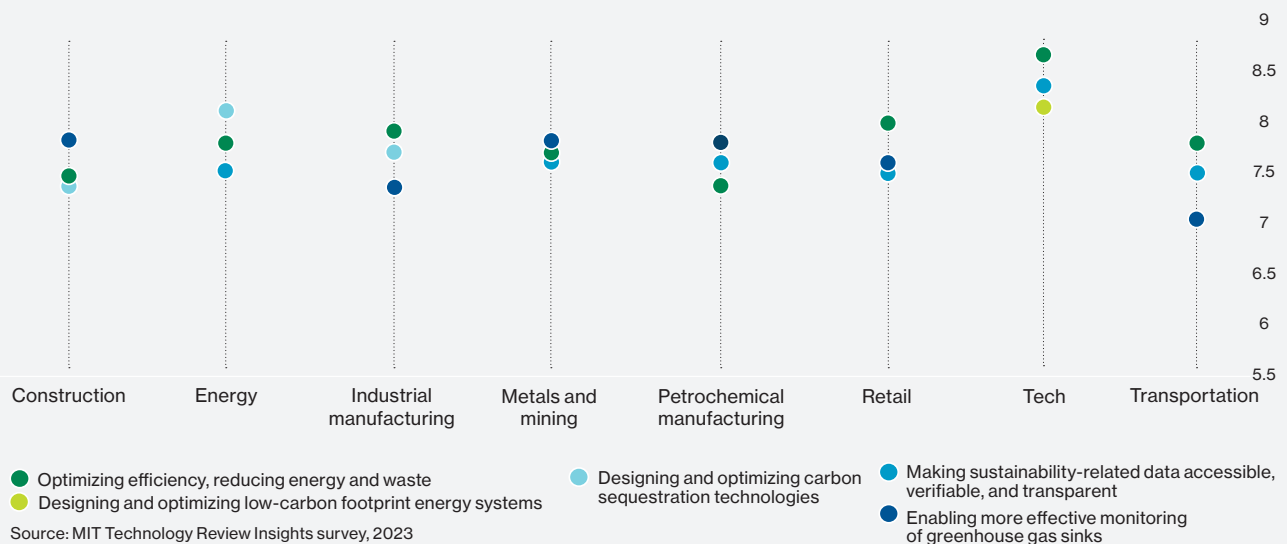
their use and plans for digital technologies to enable decarbonization. The data showed, in general, that digital technology's benefits are not yet seen as tangible or perceived as critical for decarbonization goals. Executives rated digital technology as only moderately important, with an average score of 6.4 on a scale of 1 to 10.

Optimism about digitalization for decarbonization varies

Different industries show varied levels of enthusiasm for the role of digital technology in reaching environmental targets. Energy companies broadly endorse the role of digital technology, and many are investing accordingly.

Figure 1: Digital technology will play a key role in meeting decarbonization targets

Across all industries, companies seek technological advancements to optimize efficiency and reduce energy and waste. On a scale of 1 to 10, with 10 being the highest, respondents ranked the top three ways digital technology aids in achieving their decarbonization goals.



However, some energy-intensive industries lack forward momentum because they are difficult to decarbonize, and digital solutions are immature. Only the technology industry is optimistic, overall.

However, the energy sector is eager to develop carbon sequestration technologies: The high share of hydrocarbons in the global energy mix means that for energy companies to meet their decarbonization targets, carbon capture and sequestration is essential, especially factoring in GHG Protocol Scope 3 emissions that can be traced back to a company but not directly produced by it.

Industries need solutions that are economical, reliable, and scalable. Satya Seshadri, associate professor at the Indian Institute of Technology, says “a lot of maturing is required.”

Solutions must also precisely fit each region and industry, says Stephanie Jamison, global energy and materials lead at Accenture. “Every situation is different; there’s not a single playbook that works everywhere,” she says.

The interconnectedness between digital technologies and energy transition is evident in energy-intensive industries such as cement manufacturing, where the production runs around the clock, and energy interruptions mean severe losses. This industry balks at abandoning access to fossil-fuel powered, continuous energy. “The biggest challenge we face [for renewable energy] is intermittency,” says Raj Narayanan, chief manufacturing officer at UltraTech Cement. “We still have some way to go before around-the-clock power from renewable energy is available.”

Digital technology enables business transformation

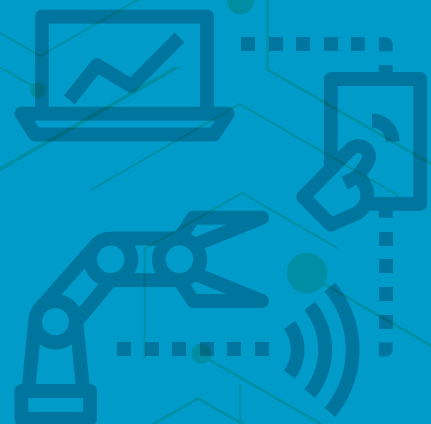
Digital technology can accelerate necessary transitions across a wide range of energy system use cases.

- **Green energy production, storage, and delivery.** Intermittent renewable energy sources require smart, decentralized grids to provide reliable replacements for hydrocarbon sources.
- **Design optimization.** Digital twins and other advanced simulation technologies can solve complex optimization problems, such as the design of wind turbines for maximum energy production or industrial processes to minimize energy usage and waste.

- **Tracking and tracing.** Verifying sustainability claims requires fully traceable digitized supply chains and carbon and emissions tracking. Developing fully circular or recycling economies will require the ability to track materials through their entire lifecycle. Blockchain may improve the transparency and verifiability of such tracking.

- **Consumer consumption.** End users of energy products now expect fully transparent and personalized insight into their energy choices, consumption, and usage patterns. Customer-facing IoT sensors, digital dashboards, and advanced analytics can drive customer trust and loyalty.

- **Governance and compliance.** Increasing requirements for data collection and analysis coupled with massive data volumes and growing data complexity call for more sophisticated reporting, data science, and audit tools.



Take, for example carbon sequestration technologies, which the energy sector is eager to develop. The high share of hydrocarbons in the global energy mix means that for energy companies to meet their decarbonization targets (especially Scope 3 standards), carbon capture and sequestration is essential.⁶ Digital technologies are critical to monitor sequestration, identify any anomaly in a plant's operations, and keep transparent and trustworthy records of the quantities of carbon dioxide stored.

Digging deeper to understand these specific industries will help accelerate innovation. While mining, for example, faces economic pressures that would tend to encourage digitalization, the industry is rated 30% to 40% less digitally mature than comparable industries by Boston Consulting Group.⁷ Understanding its starting-from-behind position and its unique challenges, such as remote and non-networked work sites, can help identify that industry's digital accelerators.

Survey data shows an industry divide in attitudes toward new digital technologies in general. Respondents from the metals and mining, industrial manufacturing, transportation, and petrochemical manufacturing are the least willing to experiment with digital technologies, and the most likely to use them only in a limited way.

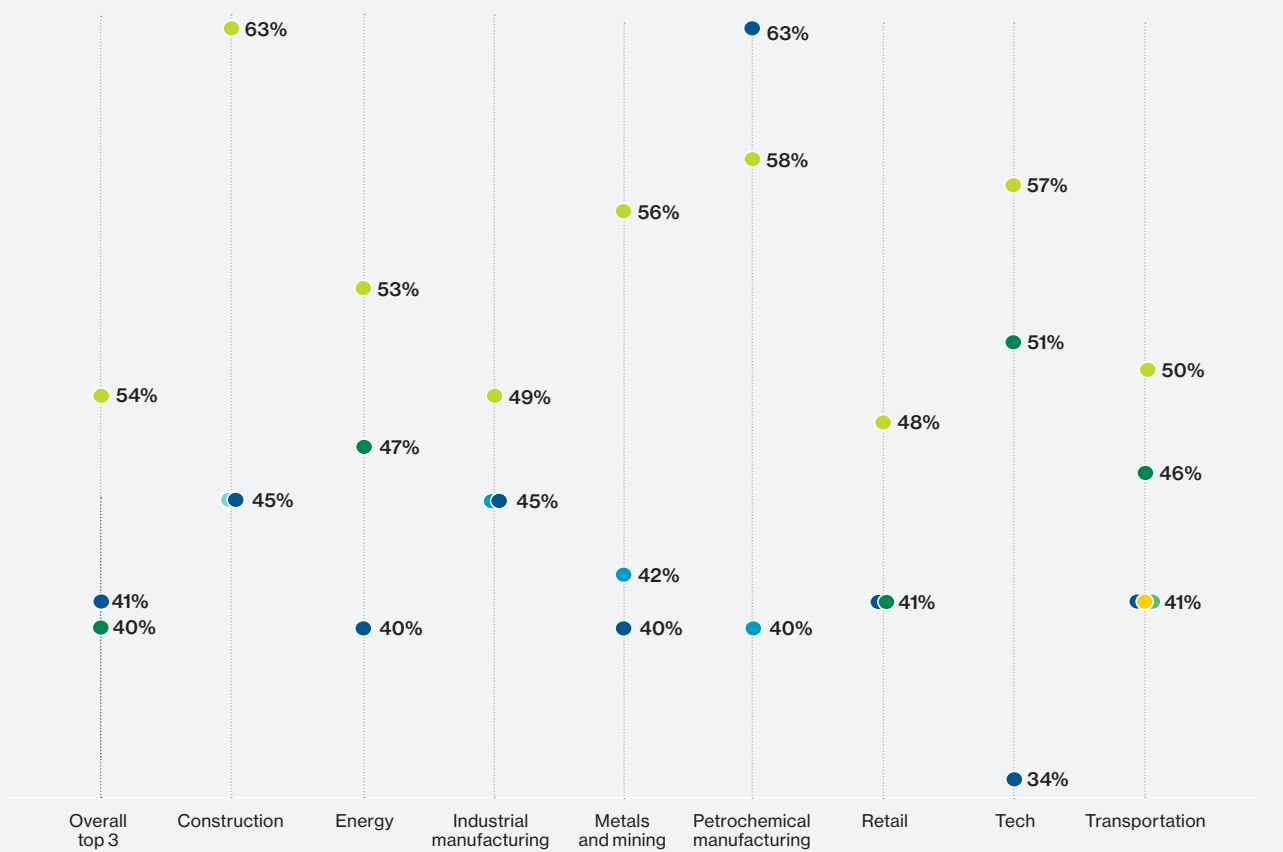
Energy industry leaders, again an exception, show a high willingness to experiment with new digital technologies, and more openness to new technologies in general.

Figure 2: All industries are investing in the circular economy

A top environmental sustainability goal for all industries is reusing, repurposing, and recycling materials, moving away from a “take-make-dispose” mentality.

- Improve energy efficiency
- Improve resource use efficiency
- Circular economy
- Zero waste
- Zero pollution
- Improve/protect biodiversity
- Improve access to clean energy

Respondents chose their top three environmental sustainability goals. In some cases, there were ties.



Source: MIT Technology Review Insights survey, 2023

Energy stands out as a digitalization leader

To succeed, the benefits of digital technologies must outweigh the risks and costs, financially and operationally. In the energy sector, emerging AI technology is used to help meet decarbonization demands by oil and gas customers. Several vendors use high-resolution satellite images, spectrometers, and AI algorithms to measure GHG concentrations of methane and carbon dioxide. Although more expensive (for now) than bottom-up emissions calculations, Stephane Germain, founder and president of emissions measurement firm GHGSat, says it is more reliable. “There is direct evidence of an emission versus an estimate,” he says.

Dan Jeavons, vice president of computational science and digital innovation at Shell, cites his company’s application of an algorithm to a liquefaction unit for natural gas, which he says has a proven potential to remove 130 kilotons of carbon dioxide yearly from the operations. This, he says, is equivalent to taking 28,000 vehicles off the road in the U.S. “Digital is a lever that has sat there waiting for us, and you can pull it right now to help you on your path toward net zero. Digital technology is going to be fundamental to running the future energy system.”

Different industries set different priorities

Companies are faced with decisions about where and how best to deploy digital technologies. Jamison helps clients at Accenture with this process: “Regarding energy transition and the use of digital technologies, it comes down to where to take specific bets. We can’t place bets everywhere and have to focus on the key barriers and opportunities.”

When asked to choose the top five ways digital technologies could help meet 2030 emission-reduction goals, survey respondents’ views are mostly scattered. Only the energy industry has a majority view, for improving existing processes (56%). Across other industries, no one answer surpasses the 50% mark. For example, the option of using digital technologies to accelerate laboratory testing and R&D was the most selected by petrochemical manufacturing respondents (50%), but the same choice is a bottom-three selection for industrial manufacturing and construction.

Top responses differed by industry. Using digital technologies to offer new products and services is a top response in metals and mining (47%) and industrial

Industries using digital technologies for energy transition commonly start with one of these solutions:

- 1 **BASE-LEVEL CONNECTIVITY:** IoT sensors measure GHG emissions, and data is processed in real time and remotely, facilitating comparisons across facilities and a centralized view.
- 2 **DATA FRAMEWORK:** Daily data gathering can quickly generate trillions of data points. Data warehouses and data lakes store data on site or in the cloud, in the right format for reporting, analysis, or ML.
- 3 **OPERATIONAL INSIGHTS:** Structured data can help set up systems to build operations and find efficiencies. AI and ML outstrips human ability to automate processes, manage large amounts of data, and see insights.
- 4 **MODELING:** AI and ML is key to modeling techniques such as digital twins that can help develop new solutions. While novel, these techniques promise acceleration of R&D processes.
- 5 **MARKETS-BUILDING:** Blockchain technology promises to provide trustworthy, transparent, and accountable transactions. It could be vital to carbon credit markets and new business models in decentralized energy systems.



manufacturing (40%). The energy sector, however, prioritizes using them to improve existing processes (56%), as do transportation (43%), technology (43%), and retail (41%) executives.

Executives are divided about improving current processes vs. investing in R&D. Almost half of respondents from the construction sector are interested in creating new business models with digital technology, for example, in contrast to less than one in five from transportation and petrochemical manufacturing.

Similar variations are visible through the lens of job function. When comparing the three most selected choices and the three least selected, there is seldom an answer different job functions agree on. When rating the role of digital technologies for process improvement in support of decarbonization targets, chief operational officers (COOs) give it a prominent role (48%), while chief digital officers rate it one of the least important (28%). Similarly, when rating the ability to analyze data faster, chief data officers see the benefits (46%), whereas only one in four chief security officers (CSOs) do.

If digital is one of the easier levers to pull to deliver immediately on decarbonization targets, this lack of aligned commitment from within industry sectors raises concerns. Innovation must happen quickly, and collaboration is key – and it will help build digital capability in all industries.

Cloud enables transformation and AI

Survey results confirm companies are making progress toward net-zero transition using digital technologies to run existing tools more efficiently. Cloud computing, for example, helps decrease carbon footprints by using less energy, and also facilitates big data, AI, and ML. Switching from an on-premises data center to a cloud-based one optimized for hyper-scale efficiencies can substantially decrease direct energy consumption.



Figure 3: All industries are cautious toward new tech adoption

Respondents selected one description to characterize their company's approach to technology adoption.

We build partnerships with technology provider to innovate digital solutions	31%
We use relevant digital technology available once they have matured	24%
We support actively the development of broad-open innovations ecosystems	15%
We experiment with digital technologies early on	11%
We use digital technologies in a very selective and limited manner	11%
We are apprehensive about new technologies	8%

TOP CHOICE BY INDUSTRY

We build partnerships with technology providers to innovate digital solutions

20% 40%

6 out of 8 respondents choose to build partnerships.



Source: MIT Technology Review Insights survey, 2023

“You need the CEO on board, you need the CFO on board, you need data security on board. Digital transformation goes through the whole company, and it has to be driven from the top.”

Peter Maier, Senior Vice President,
Strategic Customer Engagements,
Office of the CEO, SAP

Peter Maier, senior vice president, strategic customer engagements, office of the CEO at SAP, says cloud provides agility, flexibility, and scalability. “Cloud computing can also make digital transformation easier. Companies can try out new processes before making a final purchase. Rollout of new solutions is much faster if you stay close to the standard – and you don’t have to worry about hardware and installing software,” Maier says.

Germain concurs for cloud alongside digital transition. “For us, the cloud represents scalability. Today we have six satellites, we have another six launching next year and then we’re in the process of raising funding for scaling that up significantly. For that kind of scalability, you need a backend, a processing infrastructure that can scale with you,” he says.

Cloud-based services and edge computing – a method of using and storing data close to its source – means access to a growing offering of AI and ML applications. Technology giants such as AWS, Google, Microsoft, and SAP, as well as ecosystem partnerships like the Open AI Energy Initiative offer catalogues of AI and ML-based services that help detect failures or abnormalities in machine functions, and predict when maintenance is needed. “AI applications can automate and optimize a wide range of business processes; for example, it can identify and even resolve implausible meter readings for utilities companies,” Maier says.

Shell’s Energy and Chemicals Park in Rotterdam exemplifies how AI applications benefit existing premises. Since its digital technology retrofit, the site is monitored by AI algorithms that detect potential leaks, and Shell says it has prevented a series of errors. AI is also used for advanced corrosion monitoring, and image-based inspections that detect anomalies invisible to human inspectors.

In the cement industry, AI and ML help produce a standardized product from raw materials that vary in quality and composition. Narayanan says digital technologies can easily accommodate differences in manufacturing parameters such as resource quality, climate conditions, and equipment temperature. “The human mind can only connect a few parameters at a time; with machine learning, we can compare large amounts of data simultaneously and then see the effect of these properties on the final product,” he says.

The use of AI and ML to develop products and facilities is growing, such as construction of power plants or transmission build-out. “We can easily reduce the cost of capital delivery by 30% by using digital technologies, such as digital twins, which enable you to optimize the design and construction process ahead of starting build, and underpin lower operational costs throughout the life of the asset,” Jamison says.

“Connectivity enabled by digital technologies carry the enormous power of cutting global carbon emissions. 5G, Internet of Things, artificial intelligence, digital twins, blockchain, satellite technologies, and so many others can help to reduce them by 15% by 2030.”

Thierry Breton, EU Commissioner, COP26 keynote



Figure 4: Top five ways digital tech will help industry in the next 18-24 months

Respondents ranked the top five ways in which digital technologies can help achieve their company's decarbonization goals.

Top five overall (all respondents)



Top choice by industry



Top choice by role



Source: MIT Technology Review Insights survey, 2023



Upstream, downstream, and the importance of partnering

Supply chains are critical to industry capabilities to deliver products and services. Managing relations with thousands of suppliers, coordinating across the value chain, and collecting data for operational and strategic planning or reporting is not simple. Operations and transactions that cross international borders add further complexity. To reach net zero, these industries need to measure carbon throughout the supply chain. This will be a core requirement to access AI and ML's ability to conquer the complexity of strategic and organizational planning.

Yet very few survey respondents (16%) identify open standards and ability to share data as their top accelerator for digital technology adoption. Respondents in energy (11%) and construction (8%) are particularly unlikely to call open standards and data sharing their key enabler, despite their importance in developing the level of supply-chain partnerships net zero requires.

Understanding why organizations are not prioritizing this form of collaboration – and working to change that – will be key to reaching net zero. Some avenues already exist, such as the Open Footprint Forum of the Open Group,⁸ which developed a data platform to create a common model for footprint-related data for emissions, consumption (water, land, and energy), and base calculations to normalize and aggregate data.

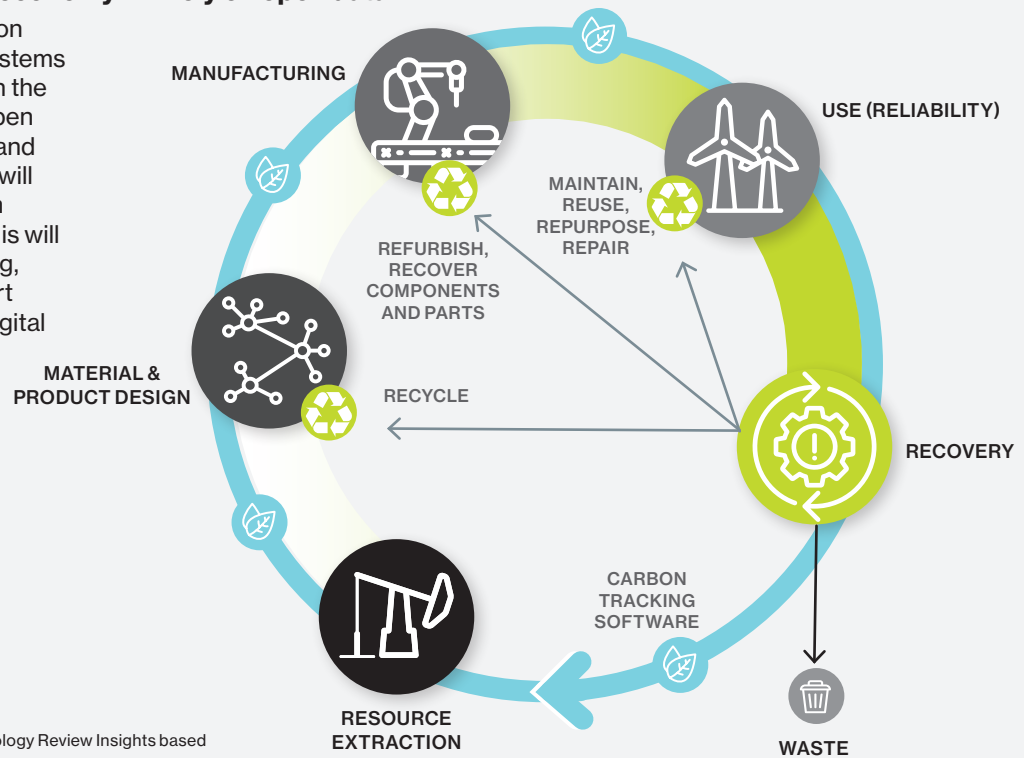
Streamlining the supply chain is “inevitable” for net-zero transition, and supply chains must change, says Scott Guthrie, executive vice president of Microsoft's Cloud and AI group. “Each step along the value chain is a different data point that's often owned by a different organization. Data and AI are going to be essential for being able to predict not just how to ship a product with the least carbon, but also to anticipate customer demands,” he says. Manju George, head of strategy for the World's Economic Forum's platform on digital economy, agrees. “Without data sharing, without common metrics and frameworks, decarbonization of supply chains just cannot happen,” she says. And as the World Business Council for Sustainable Development concludes in a recent report, “businesses are in a unique position to influence supplier behaviors, operations and investments through incentives” to reduce Scope 3 supply chain emissions.⁹

Digitalization benefits are bigger than decarbonization

Access to open data that is reliable and accurate is particularly important for future energy systems. Standardized measurements, data sharing, open standards, and open source solutions allow for interoperability of digital solutions, vital functionality for collaborating, and for collecting data to report on GHG emissions. These practices offer benefits beyond decarbonization goals such as shaping circular value

Figure 5: A circular economy will rely on open data

To meet decarbonization goals, future energy systems will collaborate through the value chain. Reliable open data, open standards, and open source solutions will enable tracking carbon through the system. This will be vital for collaborating, collecting data to report GHG emissions, and digital transformation.



Source: Compiled by MIT Technology Review Insights based on "PV in the circular economy, a dynamic framework analyzing technology evolution and reliability impacts,"¹⁰ 2023

chains, allowing widespread adoption and scale. "Also, it can harness the collective intelligence of a larger group," George says.

Narayanan sees first-hand that data sharing fosters innovation. "Sensors and uploading data to the cloud allow multiple stakeholders to work with [the data]," he says. "For example, the compressor or heavy-motor vendors, which do not necessarily know about problems involved in the manufacturing of cement, can further develop their expertise and knowledge." He concludes, "This helps us receive inputs from experts in various fields and is going to be of great significance going forward."

Expectations for open standards vary

Survey responses indicate open standards are perceived differently across regions. For executives in North America and Europe, roughly one in five agree that open standards and ability to share data across supply chains and ecosystems are key enablers to accelerate deployment of digital technologies to support decarbonization. In the Middle East and Africa, less than one in 10 share that opinion, with numbers as low as 6% for Latin America.

Data also reveals differences across job functions and industry. Twice as many chief data officers (22%) value open standards as chief technology officers (CTOs) (11%). Executives in industrial manufacturing and transportation see open standards as a top priority, whereas only 8% of respondents from the construction industry do.

The Open Data Institute (ODI), a nonprofit that helps companies and governments create open data ecosystems, acknowledges creating open standards can present risk and be time and resource intensive. However, open data and data sharing is increasingly accepted as part of digital transformation.

The pros and cons of distributed energy

Given that renewable energy sources are intermittently available and, in many cases, geographically remote, future power systems are likely to involve many players and require decentralized control. These systems must also be smarter, more able to predict supply and demand, send operational signals in real time, and conduct many more transactions.

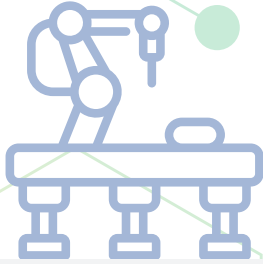


Figure 6: Innovation culture is the most important enabler for digital technology

Technology roadmaps and commitment from senior leadership also rose to the top as important digital technology enablers.

Survey respondents were asked to identify what is most needed to implement digital technologies to achieve their company's decarbonization goals. Percentages do not equal 100% due to rounding.

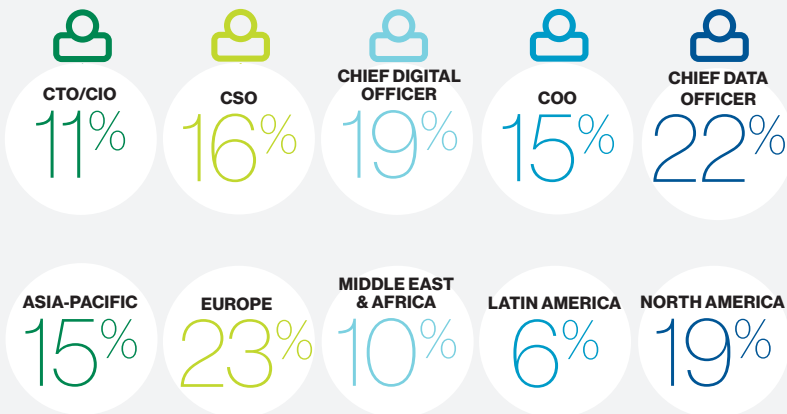
	OVERALL	CTO/CIO	CSO	CHIEF DIGITAL OFFICER	COO	CHIEF DATA OFFICER
Senior leadership commitment	17%	25%	13%	16%	21%	6%
Collaboration partners with technical capabilities, knowledge, and resources	9%	10%	4%	9%	10%	14%
Open standards and ability to share data across supply chain and ecosystems	16%	11%	16%	19%	15%	22%
Digital innovation culture with active knowledge-sharing and learner mindset	25%	25%	29%	22%	30%	20%
Technology roadmap with common platforms and quality data	19%	25%	18%	21%	11%	20%
In-house tech talent with robust talent strategies	6%	4%	10%	1%	7%	8%
Appropriate funding	7%	1%	9%	11%	6%	10%

Source: MIT Technology Review Insights survey, 2023

Figure 7: Few are ready for open standards and data sharing

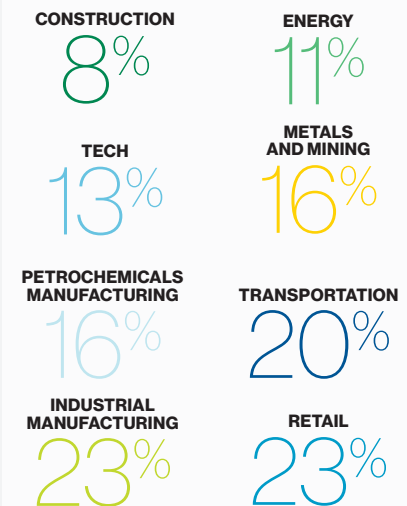
Europe is most interested in open standards, especially among chief data officers.

The percentage of respondents that identified open standards as an important digital technology enabler, by title and by region surveyed.



Source: MIT Technology Review Insights survey, 2023

Percent of leaders who say technology partners and suppliers, along with data sharing and open standards, will be needed to achieve decarbonization goals.



Hendrik Sämisch, founder and CEO of virtual power plant company Next Kraftwerke, has seen fast growth in energy generation and trading. “Ten years ago, a power trader might have sent a signal to a single coal power plant to fire up, and used that flexibility to steer through shifting demand,” he says. “Now, virtual power plants have the option to control 14,000 power plants.” Technology frameworks enable this shift by managing fluctuating demand and supply, and execute millions of transactions per day. Guthrie agrees: “This is a giant data, AI, and cloud infrastructure problem that digital can help solve.”

George notes that digital technologies are a core foundation for facilitating this transition. “To transform our global energy system into something that is a lot more intelligent, a lot more decentralized, a lot more optimized, flexible, and less reliant on hydrocarbons,” he says.

Broader and deeper partnerships

For most companies, partnering with providers to innovate digital solutions is routine. Executives from five of the eight industries consider partnerships key to integration of digital technologies. For the other three, partnerships are the second most likely approach. “It’s a long journey toward the energy system of the future, but the hurdles are not in the technology,” Sämisch says.

Partnerships are key to solutions for individual companies and sectors. Narayanan’s team works and shares data with Global Cement and Concrete Association (GCCA) members, focused on digital technologies and new engineering solutions. Jamison agrees this approach mitigates risks and spreads costs. “One of the biggest risks that has to be managed is investing in the right technology at the right time given the rapid pace of development,” she says.

Securing carbon markets

Carbon emissions trading schemes (ETS) exist in several regions (California, China, and the EU). These are a form of carbon pricing or carbon tax, which limit annual emissions industries can produce per year. Companies that do not use attributed carbon permits can sell unused carbon credits on private markets.

Carbon offsets use the same unit of measurement – a ton of CO₂ emissions – but are created through carbon projects that, for example, contribute to stopping deforestation, reforestation, or afforestation.

Carbon markets refer to markets for ETS-related credits and voluntary markets for carbon offsets. Financial market data provider Refinitiv says carbon markets hit a new activity record in 2021.

However, these carbon markets face several challenges and obstacles:

- Lack of global standards
- Lack of verification
- Differences in quality of carbon offsets
- Need for scientific evidence

A study by SaaS company AiDash in January 2023 says 43% of businesses rely on carbon offsets for GHG emissions commitments. However, 41% of companies avoid using carbon offsets due to trust issues. Narrowing this trust gap will be essential to widespread adoption of these carbon markets.

Web3 technologies, and particularly blockchain, which creates a decentralized, fully verifiable ledger, may address this need for trust and transparency for carbon markets.¹¹ According to the U.S. Government Accountability Office, blockchain can provide a high level of security for ledgers.



04 Forming digital coalitions to overcome challenges

Despite the promise of digital technologies for energy transition, obstacles persist. Energy transition experts advise that energy and digital transitions should proceed together. “The combination of digital and energy tech, combining that with human ingenuity, is what’s going to make the energy transition happen,” says Jamison. “This is evident in the incredible progress we have already made in areas like offshore wind.”

Human ingenuity is fostered through culture. One in four survey respondents confirm a digital innovation culture – encouraging active knowledge-sharing and a learning mindset – is key to accelerating use of digital technologies for energy transition. This is followed by implementing a technology roadmap (19%) and senior leadership commitment (17%). These enablers emphasize processes and systems, as opposed to hard skills.

Globally, only 6% of executives see “in-house tech talent with robust people and talent strategies” as an enabler. Only in the Asia-Pacific and in the industrial and

petrochemical manufacturing sectors do more than 10% of respondents propose talent can close the gap. The right culture formalizes processes that factor in multiple views. Executives often have different and sometimes opposing priorities. Culture can help give opinions a voice, which helps the CEO make decisions.

In strategic customer engagements, Maier views change management as the biggest risk during digital and energy transition. “You need the CEO on board, you need the CFO on board, you need data security on board,” he says. “Digital transformation goes through the whole company, and it has to be driven from the top,” Maier says.

CEOs can drive transitions

Transitions require extensive changes, Jamison says, and the CEO needs to provide leadership. “It’s a question that we get a lot: Who within an organization drives the energy transition?” she says.

Seshadri agrees that CEO leadership must drive changes. He says: “Normally, the conversation starts at the CEO

“The combination of digital and energy tech, combining that with human ingenuity, is what’s going to make the energy transition happen. This is evident in the incredible progress we have already made in areas like offshore wind.”

Stephanie Jamison, Global Energy and Materials Lead, Accenture

level, or at least at the CxO level. Bottom-up very, very rarely works, in this case.” Middle and lower management are not in the position to drive digital transition because the changes are beyond their scope, Seshadri explains. Strategic decisions should be made at the top, and middle management can explore how best to execute them.

Jeavons concurs on the value of CEO leadership, and points to digital adoption and absorption as challenging bottlenecks. “How do you make sure that the capacity of the organization is actually there to absorb these technologies as they emerge?” he asks.

Cybersecurity worries are slowing progress

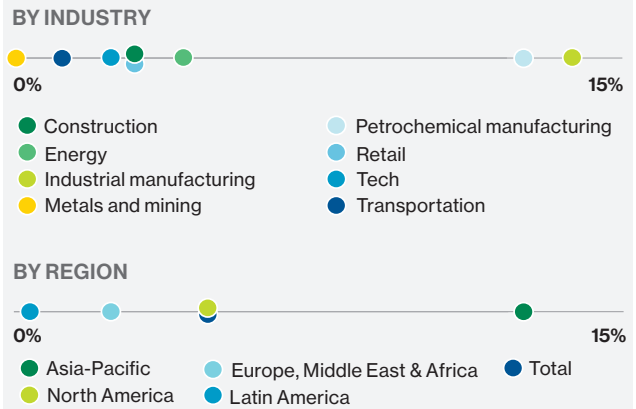
Cybersecurity is identified as the main external obstacle to digital transformation for decarbonization by almost six out of 10 respondents, with construction companies most worried (78%) and metals and mining the least (47%). “Providing world-class cybersecurity is essential for your license to operate as a technology and cloud provider,” explains Maier.

For George, “the security and cyber resilience aspect is particularly important for the energy sector, as it is a critical infrastructure.” McKinsey explains there are three primary concerns for companies in the energy sector specifically: 1) an increasing number of threats; 2) the expanding attack surface of utilities; and 3) physical and cyber infrastructures, which are increasingly interdependent. Cyber risks stem not only from software, but also hardware, Seshadri says. Microcontrollers are commoditized and

Figure 8: Leaders need to prioritize in-house talent development and strategies

Culture and talent development is a significant aspect of an effective strategy to reach decarbonization goals through digital technology implementations.

Respondents were asked to identify key enablers for accelerating digital technology deployments to achieve decarbonization goals; this figure shows the response related to talent development.



Source: MIT Technology Review Insights survey, 2023

Blockchain and air travel decarbonization

Sustainable aviation fuels (SAF) are renewable or waste-derived fuels that can be blended with jet fuel or used alone to help decarbonize air travel. However, SAF is two to eight times more expensive than standard jet fuel. While large companies may be willing to pay for SAF in support of net-zero pledges, they need a direct way to signal the demand to secure the benefit of the fuel.

Enter blockchain.¹² It provides the necessary traceability and verification to address these challenges. Avelia, launched in June 2022, is a **digital book and claim platform** that uses blockchain technology to trace SAF from production to its entry into the fuel supply. A collaboration between Shell, Accenture, and American Express Global Business Travel, Avelia allows for straightforward demand signaling and assignment of sustainability impact.

unsecured. “You really don’t know how secure they are and how secure their protocols are,” he says. But commonly, if not used in critical infrastructure, the only concern is cost, he says. Yet, a simple device such as an air conditioner can be critical if it is an integral part of a data center. On the software side, security risk can emanate from people who design it, Jeavons says. “You could embed human bias into an AI system very, very easily,” he says.

Like commercial airplanes that could fly without a human pilot, some leaders wonder if and when to take the human out of the equation Jeavons says: “The step toward fully autonomous control is oftentimes a step too far for most people to accept. The risk of it going wrong is simply too great.”

Calls for regulation and innovation ecosystems

Regulation, especially of sustainability goals, is a driving force and varies across sectors and geographies. Some companies’ net-zero plans bank on digital and engineering technologies that are not yet scalable nor economical,¹³ but regulation could help. Fifty-four percent of respondents identify lack of regulation as a risk, especially CTOs and CSOs. North America’s preference for industry standards over regulation is unique: the rest of the world prefers stronger guidance from government, particularly the Middle East and Africa, and the two largest populations, China and India.

Some see an obvious need for governments to set standards and hold companies accountable. “If you have a data breach or you don’t take security seriously, or you misrepresent how you’re using data, or you use data you’re not supposed to, there needs to be legal consequences,” Guthrie says.

Others think governments should provide space for technology and governance structures to develop in parallel. “We need to create more space for instruments like sandboxes because the pace of change of technology is so much faster and exponential than what we had before, and I think it is just impossible for regulation to keep pace,” says George. She stresses principles such as agile governance and anticipatory regulation.

Innovation ecosystems help development of new products and business models, ideally, across sectors. “Between energy, electrification, and technology, all of these categories are merging together and new

players are emerging across them, so I think more collaborative business models can emerge as well,” says George. Collaborations spanning the energy, maritime, and mining sectors, for example, could generate fast-charging solutions for mining’s heavy-duty e-vehicles and a smart-microgrid infrastructure to enable this electrification.

Trusted partnerships mitigate financial risks, foster innovation, and keep costs down, and are vital for energy transition, Jamison says. “It’s knowing what your partners are building, knowing what you’re getting, and testing it to some extent; knowing the space, knowing which products are leading and meet your needs, staying really close to those partners, and having them at the table,” she says.

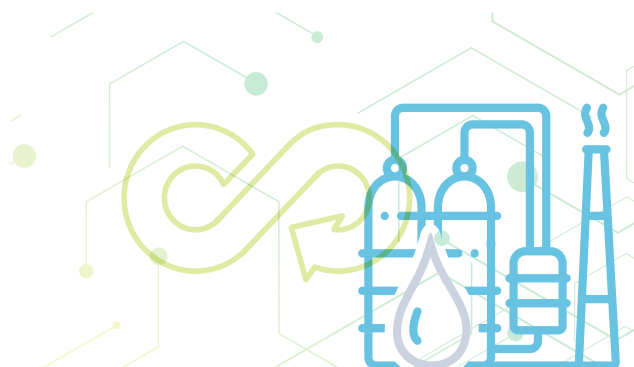
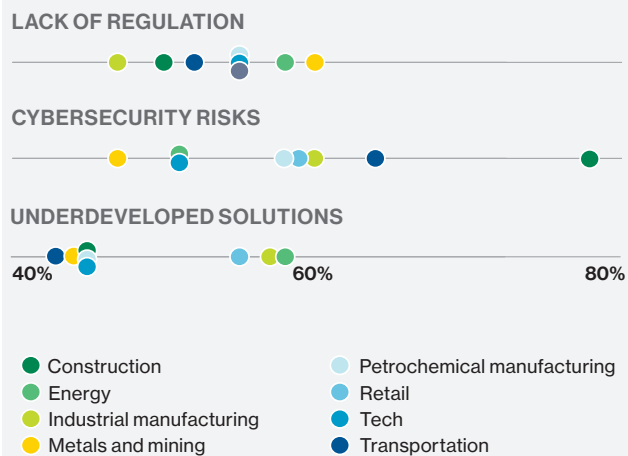


Figure 9: Cybersecurity, regulation concerns unite all industries

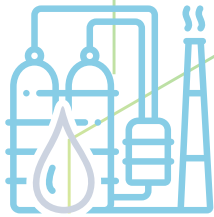
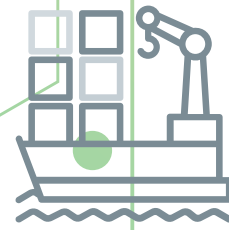
Security threats, along with lack of regulation and underdeveloped technology, concern industry leaders when it comes to reaching decarbonization goals.

Respondents were asked to identify primary external obstacles to the rollout and use of new digital decarbonization-friendly technologies; this figure shows the top three responses.



Source: MIT Technology Review Insights survey, 2023

05 Conclusion



Jeavons aptly summarizes the opportunity: “Digital has the ability to create incentives and new business models to accelerate the energy transition.” This research shows a strong connection between energy transition and digitalization efforts. It suggests that these efforts are not proceeding with the necessary urgency.

Some sectors remain cautious: underdeveloped solutions can be risky and costly. A McKinsey report estimates digital technologies can decrease operational costs by 10% to 30%¹⁴ but also increase energy needs. It is important to “make sure that the net carbon footprint of digital technologies remains positive,” says George, emphasizing the importance of carefully evaluating the net impact of digital technologies.

But while many organizations have long favored a conservative approach, both in adopting digital technologies and in shifting to net-zero solutions, the time has come for decisive action. Established organizations may feel most comfortable taking a “customer-back” approach to these challenges: assessing their customers’ unmet needs around their sustainability goals and then developing digital capabilities and solutions to meet them.

The urgency of those needs can drive quick innovation, and the resulting bespoke decarbonization and emissions-reduction pathways will be beneficial to the supplier, the customer, the industry, and the planet.

Research points to the growing potential of digital technologies, particularly AI. The frontier lies in technologies like artificial neural networks and quantum computing. In the near term, these capabilities will continue to grow. To be ready, and to use solutions available now, industries need systems and processes in place, not least to allow interoperable data within supply chains.

Organizational culture is vital for digital capabilities to grow in line with progress in data analytics, predictions, and modeling. Buy-in and willingness to experiment and learn is key for cooperation across departments and organizations. The way companies organize, structure, and use data is fundamental to enabling digital solutions. And to the extent that organizational skepticism or lack of trust hampers participation in existing solutions, such as carbon markets, both governments and individual organizations must either address the causes or proactively propose different solutions.



“The pace of change of technology is so much faster and exponential than what we had before, and I think it is just impossible for regulation to keep pace.”

Manju George, Head of Strategy,
Platform on Digital Economy,
World Economic Forum

Collaboration will also be key. Because multiple parties must interconnect for innovation ecosystems to arise and accelerate R&D, organizations must take a hard look at how they are participating in sharing data and innovation and contributing to standards that enable this. Partnerships can reduce financial risks and achieve cybersecurity across industries. Industry associations, standard-setting bodies, and government agencies should ensure governance keeps up with digital developments.

The entire global economy must participate in the transition to net zero. Energy transition can be accelerated with digital and sustainable solutions that contribute to achieving net zero by 2050. “I don’t think we’re using the full potential of digital technologies yet in energy transition plans, and in climate transition plans,” says George. “There are differences in understanding, capabilities, and language between the digital community and the climate community. I think we need more activities to bring those two disciplines together, and people with skills to do that.”

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