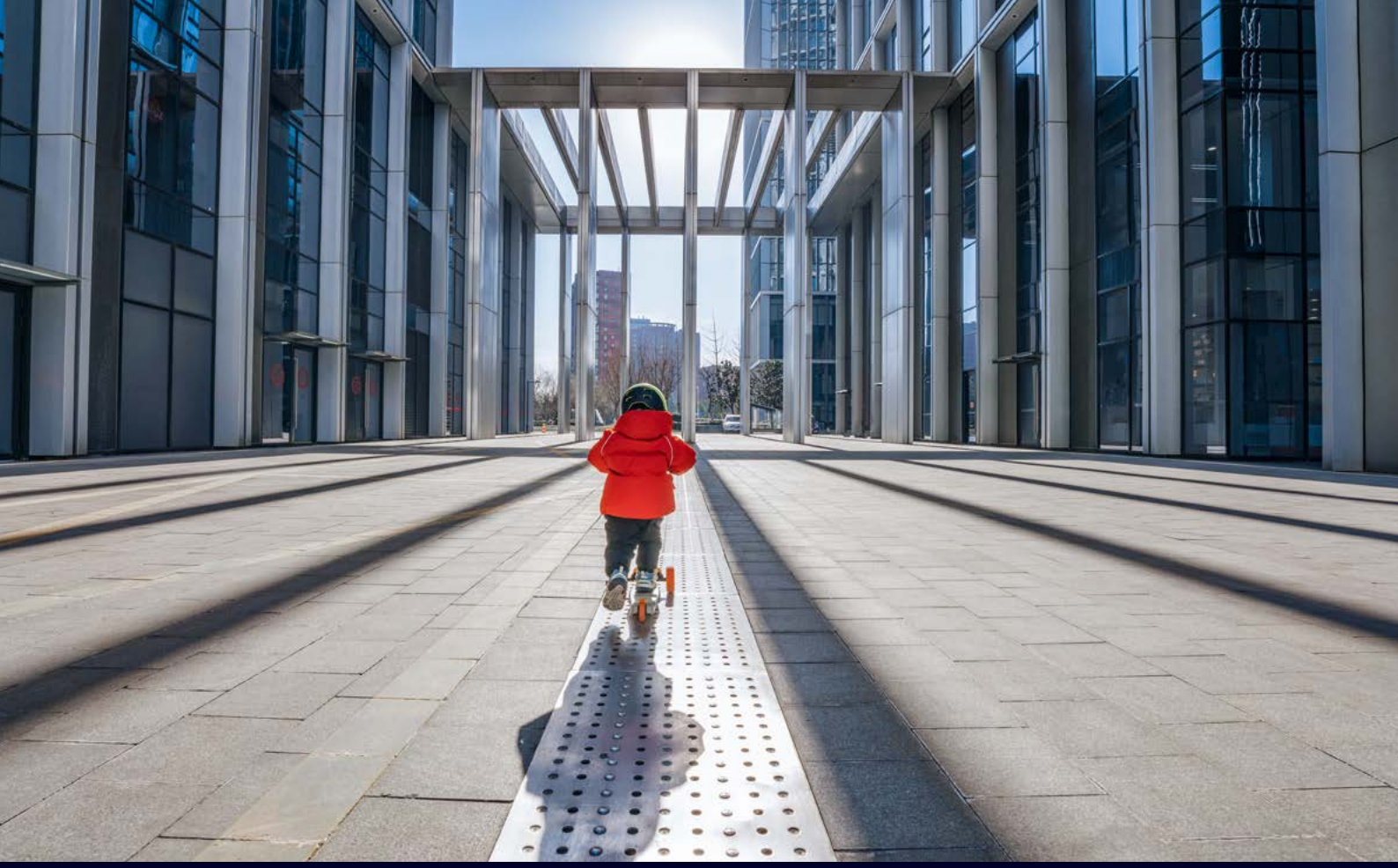


THOUGHT LEADERSHIP REPORT

A New **Space Race**

No rivals, no rockets, no thrill-seeking billionaires – this is a race for earth's space, set in our physical and digital infrastructure, the spaces where we work, live and move. This is a race against time – a race we can only win by working together.

SIEMENS

This thought leadership study reveals how infrastructure stakeholders view the immediate and longer-term future of our built environment and energy systems. Discover fresh perspectives on how our infrastructure will be reshaped by the global pandemic, a new era of digitalization and the urgent need to decarbonize.

It is not an academic or scientific research paper. Our goal is not to provide any final answers, but rather to start conversations, stimulate thought, and encourage infrastructure stakeholders to reflect on what today's megatrends mean for the future of our energy system and built environment.

The survey included 501 respondents from 10 countries. The countries involved include those large-scale and/or highly advanced infrastructure assets and ambitions.
It was fielded in June and July 2021.

Index

INTRODUCTION

Introducing A New **Space** Race

A new space race has begun.

It is a race to transform the world; to meet the great challenges of our times.

We call it a 'race' because it is increasingly urgent. Think about how crucial it is to deliver fast responses to the hallmark trends influencing our world:

The pandemic sparked an urgent race to adapt – a race to get ahead of the spread, to keep people safe, to keep services and businesses running, and now, to build new models for the future.

Digitalization is a race into new frontiers. Organizations that lead on data and new technologies gain profitability and market share while also advancing towards shared social and environmental goals.

Climate change is a race against time. It is a marathon over decades that requires us to set – and keep with – the pace of an energy revolution.

These races are changing the spaces around us, transforming the infrastructure that supports the way people work, live and move.

But the most dramatic changes – and the biggest challenges – are immediately ahead of us.

A race to transform across three spaces

This thought leadership study is about this unusual race – a new space race, with three dimensions, that we can all win only by working together.

There is no finish line in the new space race, but there is a way to win.

Winning means growing more adaptable and resilient to shocks, tragedies and changes – like those we are living through today – and by ensuring we move quickly enough to shift the earth clear of the catastrophic climate scenarios we face.

Infrastructure stakeholders are moving forward. They are racing to adapt their assets across three dimensions – what we call 'spaces' – that echo the trends we touched on above:

- **A New Physical Space Race** – The changing needs and expectations of people in their buildings, factories, facilities, offices, homes, and surrounding infrastructure.
- **A New Digital Space Race** – The evolution of the operational backbone of physical spaces, driven by advances in AI, automation, energy technologies, connectivity, and data-driven predictions.
- **A New Earth Space Race** – The impact of physical and digital space on the planet as a whole, including a revolution in energy systems that will create a sustainable legacy for future generations.

These spaces are connected, overlapping and interdependent. We will look at each in depth, but we will also show how they are linked in a single, transformational race. We will explore the routes, the mountains to climb, the hazards to avoid, and what it will take to stay ahead.

> Our highest goals are possible if we harness the power of data and new technologies, welcome greater cooperation and keep driving innovation. Together we can win the new space race.

Matthias Rebellius
CEO, Siemens Smart Infrastructure

Executive **summary**

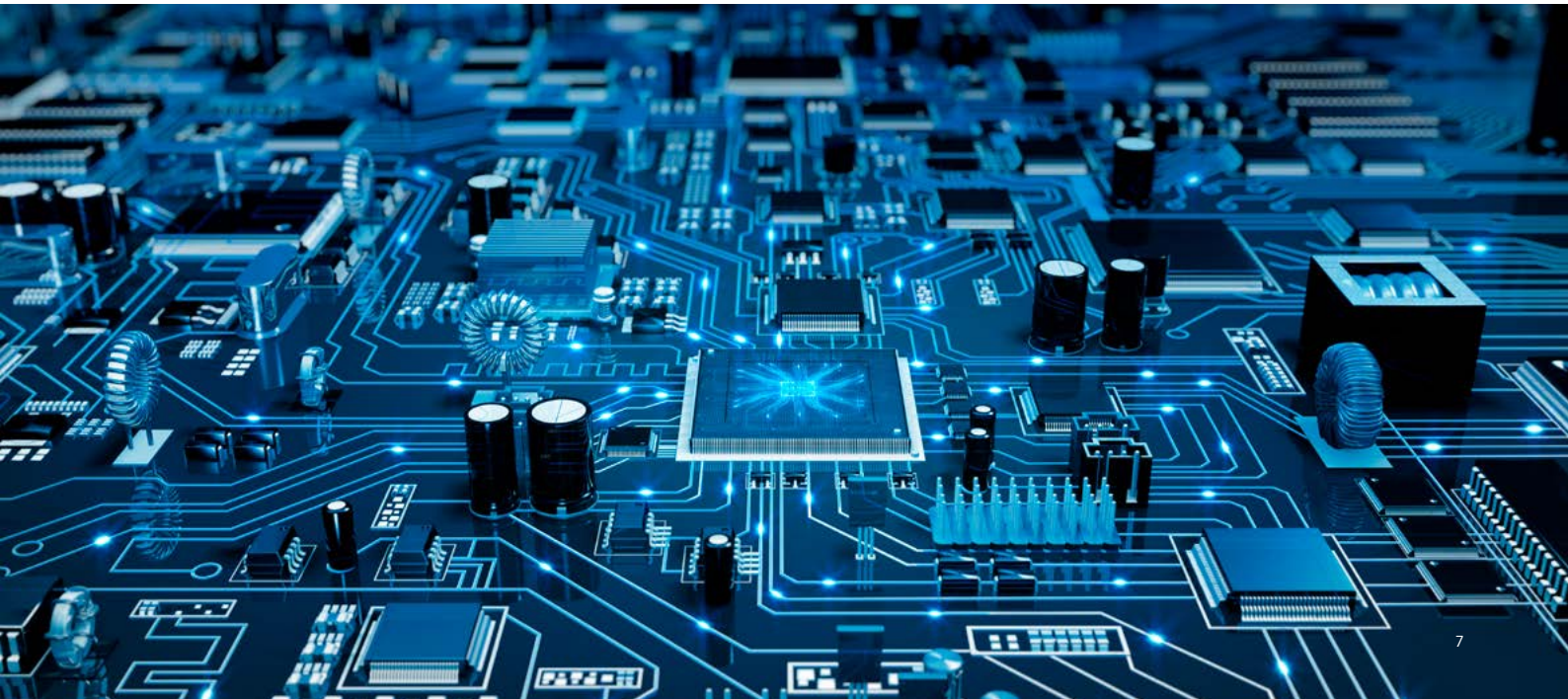
This summary outlines highlights and key findings from the full report.

Buildings in the post-pandemic world

- Some 59% of building owner/occupiers say that their organization is reducing its office space requirements to some extent in response to the pandemic.
- However, buildings will remain central – physically and figuratively – to post-pandemic commerce and industry. Two thirds (65%) of building owner/occupiers we surveyed say that, after the pandemic, employees at their organization will return to pre-2020 office/facility attendance patterns.
- Many believe hybrid work models will offer the best balance for the future, but it will take time to find the most effective approaches to suit various industries, companies, and cultures. Whatever models are chosen, buildings need to be more digitalized to support greater resilience, improved health monitoring and management systems, as well as increased flexibility, to better cope with lockdowns and other disruptive events.
- Among building owner/occupiers in our survey, future adaptability was considered the most important – and the most difficult – attribute to get right in designing a new building or facility.

A new era of infrastructure digitalization

- Two new drivers of infrastructure digitalization have emerged in recent years.
- The first is the pandemic, which has demonstrated the value of automation, remote monitoring, data-driven prediction, digitally enabled collaboration, and more.
- The second is the increased urgency of climate action and the energy transition. The world is building new energy systems that are increasingly complex, decentralized and diversified. Digital technologies are crucial to developing and operating these new energy systems.
- Most energy infrastructure stakeholders in our survey (67%) believe net zero energy is impossible without digitalization.
- Years of incremental progress and wider technological advances have led to a growing maturity in digital applications, at a time when they need to deliver on long-standing promises. But the majority of infrastructure stakeholders (63%) recognize that they are behind the digitalization progress of other industries, and only 31% our respondents have made full use of the data they have available.
- AI-driven prediction and automation looks set to have the broadest impact on infrastructure assets over the next five years. However, our findings show that many technologies will be important, and it is clear that the most impressive results emerge from combinations of digital breakthroughs. It is therefore essential that leaders maintain an innovation mindset and are supportive of new ideas and experiments.



Rising to the greatest challenges of decarbonization

- The climate is now at, or near, the top of the priority list for most infrastructure stakeholders. Over the past five years there has been an exponential rise in the number of organizations setting low-carbon or net-zero targets.
- There is a lot of optimism around achieving these goals, with most of our survey respondents expecting their organization to be carbon neutral by 2030.
- However, many organizations are still developing the detailed, viable plans that will get them to their targets.
- No organization reaches net zero alone, so targets are also dependent on progress outside of their domain, often in the energy sector, given that energy produces three quarters of global greenhouse gas emissions.
- Most respondents (82%) believe energy storage systems for homes and businesses will be a critical part of the energy transition. In addition, energy respondents rated “energy storage systems to reduce wasted energy and improve resilience” as the highest priority among a set of strategy recommendations for cities.
- On wind and solar, energy respondents see managing and storing surplus power as a much bigger challenge than coping with periods of low output. This emphasizes the importance of energy infrastructure expansion and upgrading. In many parts of the world, surplus power from wind or solar installations is wasted because it cannot be transmitted to where it is needed or stored for later use.
- Infrastructure respondents also understand the need to be smarter in how energy is consumed. An overwhelming majority of all respondents (81%) believe much more attention and investment should be given to improvements to energy efficiency and demand side management.
- Three quarters of respondents (74%) say that hydrogen will be a crucial component of the energy transition. Green hydrogen (made from renewable energy and water) is compelling because it can be a clean replacement for fossil fuels, and also used for energy storage (e.g., turning what would have been curtailed wind or solar energy into a transportable green energy commodity).
- The decarbonization of fuels is an increasingly important consideration for buildings, as greater attention is paid to embodied carbon – the emissions released in the production and transport of materials (often steel and concrete) used in buildings. Respondents rated new materials and substances as the innovation or technology they expected to have the second biggest impact in the next five years, and this could be driven by efforts to reduce embedded carbon in buildings.
- Decarbonization will rely on the combined effort of all infrastructure and energy stakeholders: over eight-in-ten (82%) respondents say increased cooperation and coordination between diverse stakeholders is crucial to reducing CO2 emissions from energy and infrastructure.

SECTION 1

A New **Physical** Space Race

The changing needs and expectations of people in their buildings, factories, facilities, offices, homes, and surrounding infrastructure.

The requirements for any kind of infrastructure often change much faster than the physical structures and systems that support them. That has always been the case, but we have rarely – if ever – seen an example of changing requirements quite as extreme as the pandemic lockdowns.

Overnight, bustling workplaces moved to suburban video calls, crowded canteens gave way to quiet kitchens, and rush hour traffic became a walk from one room to another. Suddenly, we needed radically different infrastructure.

The big question is: how will our requirements evolve from here? Investments in buildings, energy and transport infrastructure are made with time-horizons measured in decades, not years or months, so today's decision-makers need to project into the medium- and long-term, designing workplaces – and whole cities – to suit the models people settle into once today's turmoil is history.

People have changed

"I think there are quite fundamental shifts going on in people's ideas around work, where they want to work, around work-life balance and what a good life means," says Kerstin Sailer, a Professor in the Sociology of Architecture at the Bartlett School of Architecture, University College London, and co-Founder of Brainybirdz, an agency specialized in the dynamics of spatial design and organizational behavior in working environments.

Our survey highlights some of the uncertainty this is creating. For instance, nearly two thirds of building owners/occupiers in our survey say that after the pandemic employees at their organization will return to pre-2020 office/facility attendance patterns, but only 26% were strongly confident of this, and one-in-five just don't know yet (see **Fig 1.1**).

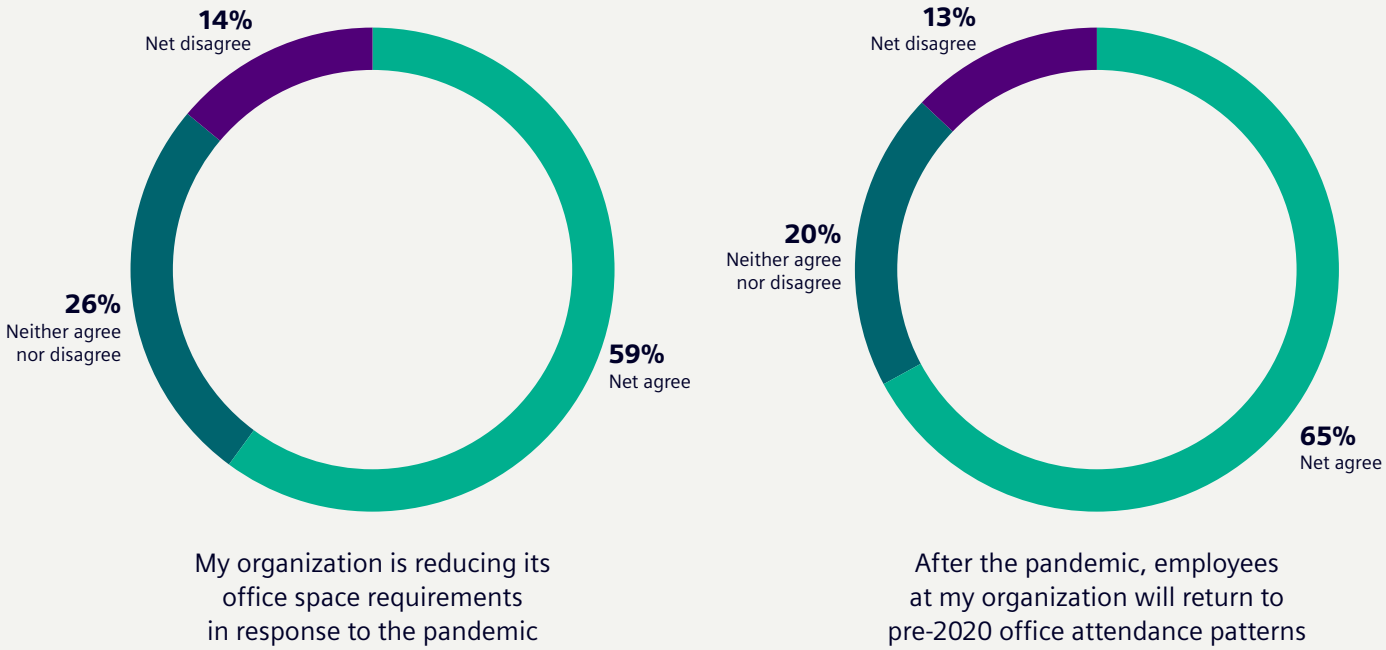
"We've heard lots of conversations in the last 18 months about the death of the office," says Jeremy Kelly, Research Director at JLL, a global real estate services firm, "but the feedback we're getting from our clients is that the office will continue to be the center of the work ecosystem."

While it may remain the center, in many cases workplaces are downsizing. Some 59% of building owners/occupiers say that their organization is reducing its office space requirements in response to the pandemic.

> The feedback we're getting from our clients is that the office will continue to be the center of the work ecosystem.

Jeremy Kelly
Research Director at JLL

Fig 1.1 The majority will return to pre-pandemic attendance patterns



While close to two thirds expect their pre-pandemic attendance patterns to return, the majority are also reducing their office/facility space requirements. [Percentages indicate the proportion that selected agree or strongly agree. Asked only of owners and/or operators of infrastructure in non-energy sectors (n=231). Those selecting "don't know/not applicable" are not shown, and as a result, percentages will not always sum to 100%.]

Firmly centralized and flexibly decentralized

Many believe new hybrid work models will offer the best balance for the future, but it is not yet clear how these models will operate, and how effective they can be across various industries, companies, and cultures.

“Everyone talks about the hybrid office – there's lots of opinion, but very little data,” says Sailer. “As a result, there are a lot of myths around how much we need to return to the office, and around what is possible or not possible remotely.”

Sailer believes companies should be using a trial-and-error approach, rather than thinking they can optimize a new model immediately. “Right now it's so hard to get right because we've very little experience,” she says.

At minimum, workplaces need to become more resilient than they were pre-2020. They need to be flexible enough to cope with lockdowns and other potentially disruptive events – as well as having better health monitoring capabilities – irrespective of whether traditional, hybrid or fully decentralized models prevail in the long term.

Digital tools will be a fundamental part of achieving these goals. “Buildings will be a lot more digital in future,” says Matthias Rebellius, CEO of Siemens Smart Infrastructure, “a facility manager will not only be able to automate, and remotely control, more functionality, they will also benefit from a wider network of better sensors that flow into integrated visualizations and richer datasets. This will support a new level of fine-grained control and insights that are needed to make future buildings more resilient and flexible.”

> Buildings will be a lot more digital in future, (...) this will support a new level of fine-grained control and insights that are needed to make future buildings more resilient and flexible.
>
> **Matthias Rebellius**
> CEO of Siemens Smart Infrastructure

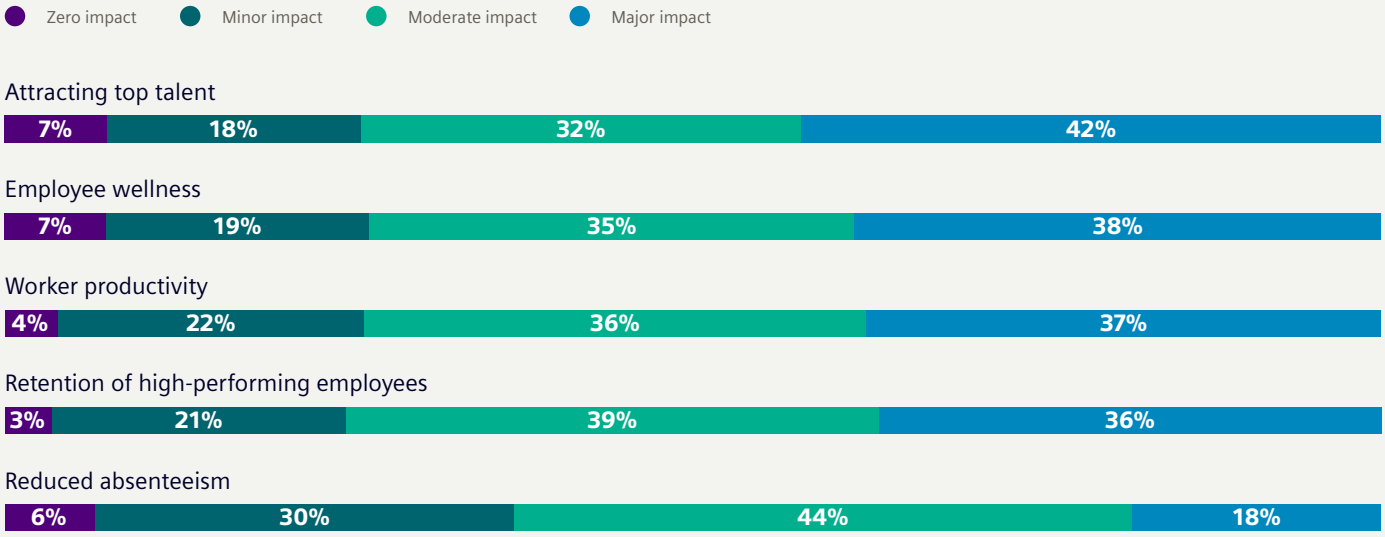
New workplace designs are blooming

Companies in some regions are already piloting various attendance models, while designing new spaces for work and making full use of technology, from new approaches to video conferencing to software platforms that enable flexible working.

These models are partly driven by a fresh set of priorities, but not all are wholly new. Indeed, both Kelly and Sailer believe the pandemic has, for the most part, accelerated trends that were already in gradual motion. For example, one only has to look at Lego's headquarters, which opened in 2019, to see that workplace design was already moving towards more varied and flexible ways of working. The fast pace of change, however, means new workplace designs have to be implemented urgently.

From a business perspective, getting new spaces and models optimized quickly is likely to drive significant benefits. Our survey reveals the extent to which building design and management can impact the profile and well-being of the workforce. Close to three quarters believe building design and management can have a major or moderate impact on each of worker productivity, employee wellness, top talent attraction, and retention of high-performing employees (see **Fig 1.2**).

Fig 1.2 Building design and management support workforce quality



A strong majority believe building design and management impacts productivity, retention, wellness, and talent acquisition. [Asked only of owners and/or operators of infrastructure in non-energy sectors (n=231). Those selecting "don't know/not applicable" are not shown, and as a result, percentages will not always sum to 100%.]

74% believe building design and management helps attract top talent.

"It's clearly driving design," Kelly says, "Architects are having to think about health and wellness, as well as being able to turn levels of safety on and off as needed. We will also see the office of the future centered much more around collaboration than it was before," says Kelly. "it's about connectivity, it's about engagement, it's about socialization."

The new importance of well-being

Wellness is a relatively new priority, covering a diverse range of factors, including physical, mental, emotional, spiritual, social and environmental contributors to our wellbeing. It is a broad, intangible, and variously defined area. This makes it challenging to incorporate using traditional methods of planning, design, and management.

> People are used to measuring costs and performance, but they are less used to measuring wellness.
>
> **Ewan Jones**
> Partner at Grimshaw Architects

"People are used to measuring costs and performance in many areas, but they are less used to measuring wellness, despite most feeling certain about the impact it can have," says Ewan Jones, partner at Grimshaw, a global architecture practice. "Some elements of wellness are easily measurable, such as light levels and ventilation, but the way a space makes you feel is much harder to quantify."

As Jones points out, it is not a science, and is still in its infancy as a consideration, relative to other metrics. "But it is now receiving much more attention," Jones says, "which is linked to the recognition from many businesses that their people are their best asset, and therefore that it is important to keep them happy, productive, entertained, stimulated, healthy and encouraged. If all your staff are happier, you could have lower absence rates, and people might prefer to come into the office, rather than working at home."

This could make wellness especially important for organizations that want to encourage more in-person collaboration in future, when the option to stay at home is likely to be much more available.

Future adaptability

When it comes to designing a new building or facility, however, the most critical factor is adaptability (e.g. being able to repurpose spaces to suit new kinds of occupants).

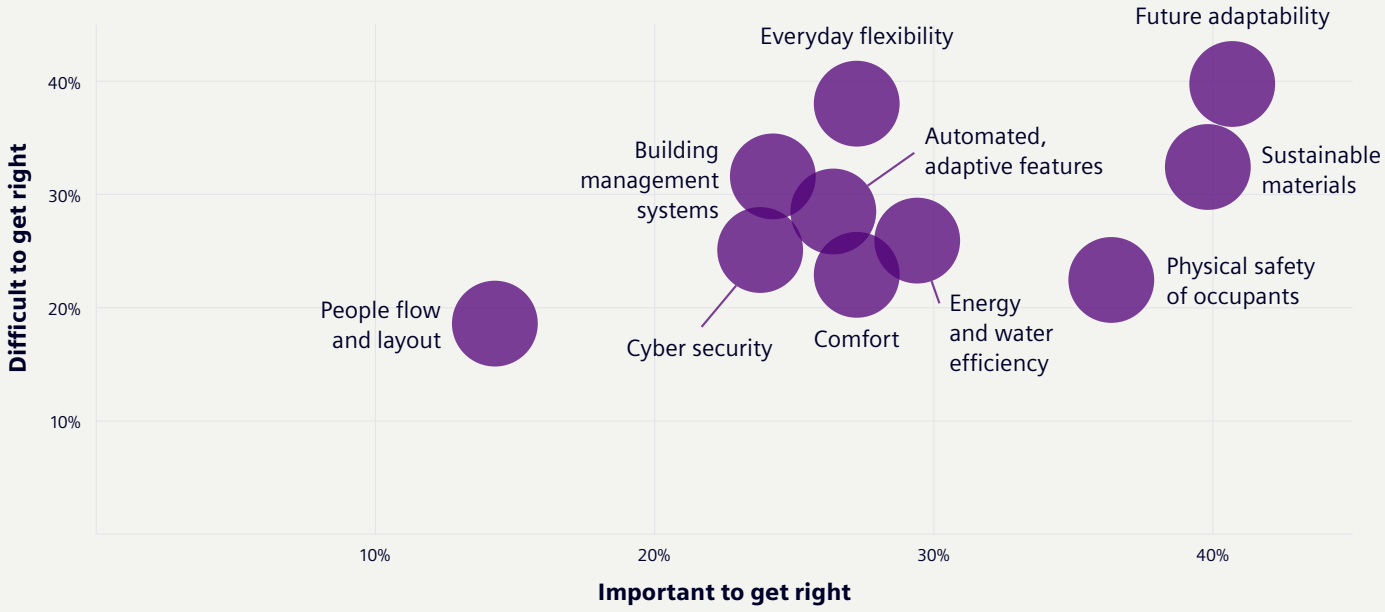
In our survey, this was deemed both the most important, and the most difficult, to get right (see Fig **1.3**).

The importance of adaptability is perhaps not surprising, given how many factors are in flux at the moment, but many expect this to continue to be a priority. "The adaptability of spaces is really going to be key going forward," says Wayne Butcher, director at Grant Thornton, a global tax, accounting, and consultancy business.

Butcher, who specializes in advising public sector organizations on infrastructure projects, believes that adaptability is important both in terms of major reconfigurations, as well as designing spaces that can change by the hour. This could include, for example, changes to suit different tasks, focused work alone, one-to-one discussions, or larger gatherings, virtually or physically.

"Adapting to remote working has already built some flexibility over the last 18 months," says Butcher, "but combining physical and virtual adaptability is now key, including how our physical environments align to a very different set of needs, which may need to shift once again at short notice."

Fig 1.3 Future adaptability: important and difficult



Future adaptability is both the most important and most difficult area to get right in designing a new building or facility. [Respondents chose up to three factors to rate as the most important, and then from the same list, another three as the most difficult. Asked only of owners and/or operators of infrastructure in non-energy sectors (n=231).]

Digitalization is a universal enabler

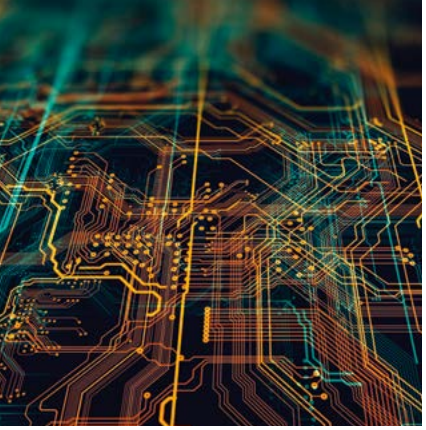
The themes we have discussed above are relevant across many industries and regions, but there are important exceptions with different drivers, goals and barriers.

For example, in many parts of the economy, the potential for hybrid work is limited or impossible – think of those in agriculture, healthcare, construction, education, cleaning, transport, hospitality, mining, physical retail, manufacturing, numerous informal industries and others. It has been estimated that more than half of the global workforce have little or no scope to work remotely.

The pandemic has been more challenging for industries where remote work has been impossible or harder to implement. Far from accelerating a long-term shift forward, these industries need to shift backwards – back to something like the pre-2020 normal – as soon as possible. But while attendance is more important, these industries are still moving forward in the digitalization and automation of their workspaces and facilities.

There is also one area where the importance of advancement is near universal: health management and monitoring. The pandemic has proven the value of, for example, automated body temperature monitoring and touchless access controls (such as face recognition). Like many of the ambitions stakeholders have for the infrastructure of tomorrow, these systems are enabled by digital technologies and new sources of data.

These can be disruptive, and at times organizations need to master a balancing act between what is feasible, legally defined and ethically justifiable. Acting with integrity and sensitivity in these realms is essential to maintaining trust and creating the contexts in which new approaches can deliver benefits. While the moral and social aspects of each case, jurisdiction and culture may vary, the majority of infrastructure stakeholders worldwide, understand that the new physical space race is inextricably linked to the maturing, digitalized, automated, data-driven reinvention of infrastructure operations.



SECTION 2

A New Digital Space Race

The evolution of the operational backbone of physical spaces, driven by advances in AI, automation, energy technologies, connectivity, and data-driven predictions.

Infrastructure has been digitalizing for decades, but there are fresh dimensions to the new digital space race. Years of incremental progress and wider technological advances have led to a growing maturity in digital applications, which are now starting to deliver on long-standing promises.

"There is transformational progress being made through the exponential growth of computing power, cloud, digitalization, and emerging technologies," says Steven Velegrinis, Head of Masterplanning at AECOM, a multinational engineering firm. "It has already transformed what our team can do, and it will grow even more powerful over the next five years."

> "There is transformational progress being made through the exponential growth of computing power, cloud, digitalization, and emerging technologies.
>
> **Steven Velegrinis**
> Head of Masterplanning at AECOM

At the same time, two new drivers of digitalization have emerged in recent years. The first is the pandemic, which has demonstrated the value of automation, remote monitoring, data-driven prediction, digitally enabled collaboration, and more. As a result, many organizational barriers to progress have fallen away.

The energy transition is digital

The second new driver is the increased urgency of climate action and the energy transition. The world is building new energy systems that are increasingly complex, decentralized and diversified.

Grids need to support the integration of renewables and energy storage systems, while managing an historic shift towards electrification, including surging demand for electric vehicle charging networks. Consumers are becoming prosumers, businesses are building microgrids, and utilities are under pressure to enable multi-directional flows of both energy and information.

The model of the past is like a river of electricity flowing from a power station, through the rapids of sub-stations, and into the many little streams that make up an analog grid. The future looks more like a water park, with flows from multiple different sources and directions, some up, some down, some combining, some disconnected, with clever plumbing and pools of stored energy to help manage variations in supply and demand.

Digital technologies will support every element of the new clean energy systems: AI algorithms optimize wind turbines; smart grids and virtual power plants balance multi-directional energy flows; building management systems adapt proactively to save power. Everywhere you look, digitalization can help us develop more intelligent and sustainable energy systems.

67% of energy infrastructure stakeholders believe net zero energy is impossible without digitalization.

In fact, most energy infrastructure stakeholders in our survey (67%) believe net zero energy is impossible without digitalization. Plus, when we asked energy respondents which strategic recommendations they would make for the biggest city in their country, the top five (out of 12 strategies) were technology enablers, which were favored ahead of legislative levers which made up four of the bottom-five (see **Fig. 2.1**).

Towards more data-driven energy systems

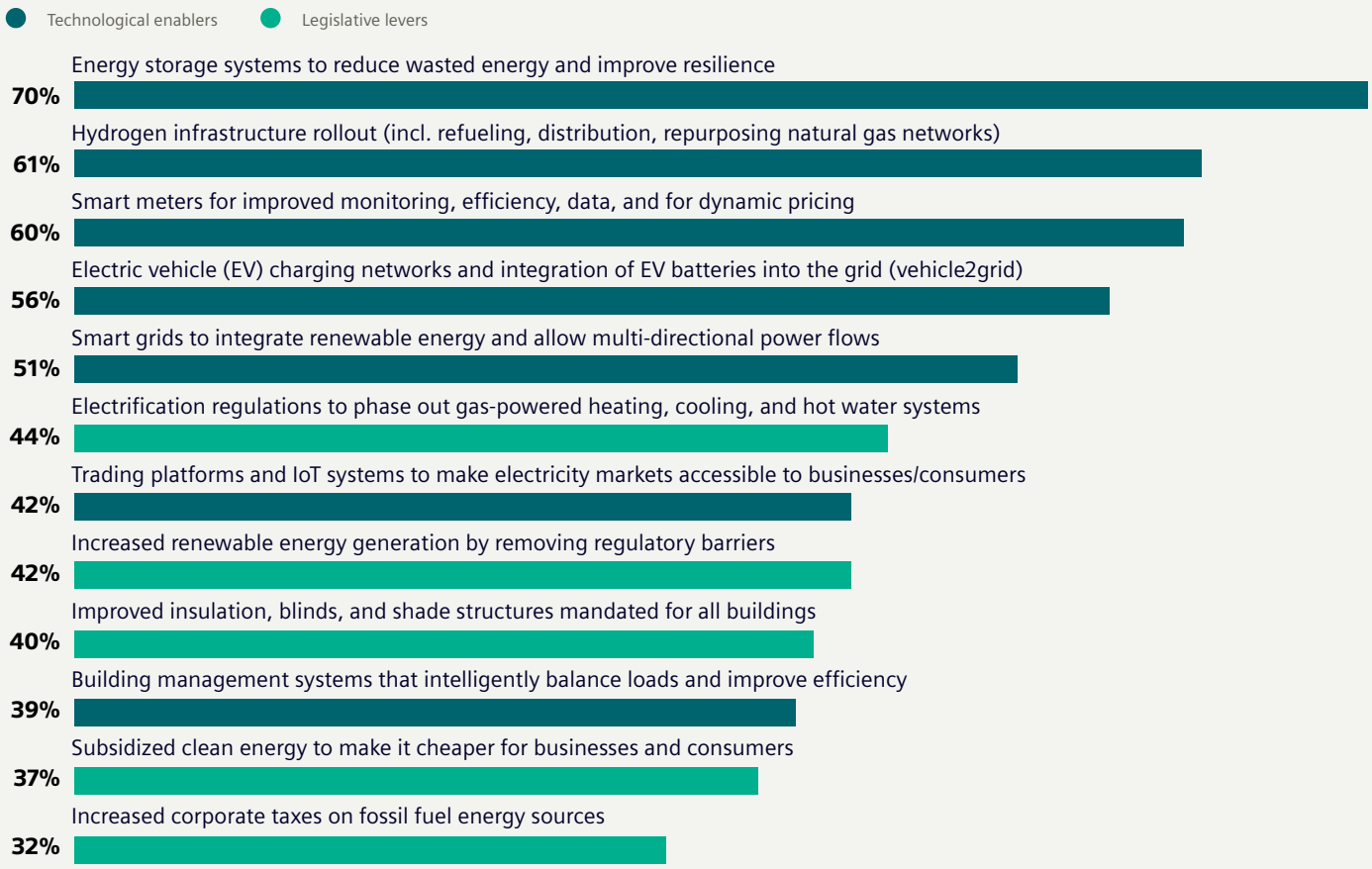
However, like any race, change needs to be fast, and the harder organizations push, the tougher it gets. “The speed of change, driven by net zero, is a huge challenge,” says Xiaohu Tao, Vice President, Business Innovation and Digital, in Energy Networks at E.ON. “For example, in 2021 e-car sales are growing rapidly. We now have over one million e-cars on German roads, and as a result of this expansion, we have needed to review our strategy many times this year.”

A big part of this challenge is that e-cars need to be charged within low-voltage grid, where many energy companies lack granular information and control, as it was not necessary in the past. “So much change is happening in the low-voltage grids that power homes and businesses, you have prosumers, e-cars, solar generation, heat-pump systems, batteries, and much more,” says Tao. “But in most of these areas of the low-voltage grid, we are blind. Once you go beyond major junctions, there is very limited information, no sensors, no switches, and no control. Huge investments are needed in low-voltage infrastructure, and in smart grids especially, to enable the transition and to support our customers.”

There may be more data at the other end of the energy value chain – in generation to high voltage transmission – but companies are only just beginning to benefit from it. “Over half of the energy that is produced is released as waste heat into the atmosphere or waterways,” says Michael Webber, Josey Centennial Professor in Energy Resources, Mechanical Engineering at The University of Texas at Austin and former chief science and technology officer at ENGIE, a multinational energy company. “The right data can help us extract value from that waste. Data can help us to refine our existing capabilities so that energy is produced more efficiently and more reliably,” he says.

> “Over half of the energy that is produced is released as waste heat into the atmosphere or waterways.
>
> **Michael Webber**
> Josey Centennial Professor in Energy Resources, Mechanical Engineering at The University of Texas at Austin and former chief science and technology officer at ENGIE, a multinational energy company

Fig 2.1 Energy sector favors technological enablers



Energy respondents favored technological enablers over legislative levers when asked which strategy recommendations they would prioritize for the biggest city in their country. [Percentages represent the proportions rating high or top priority. Asked only of energy respondents (n=57).]

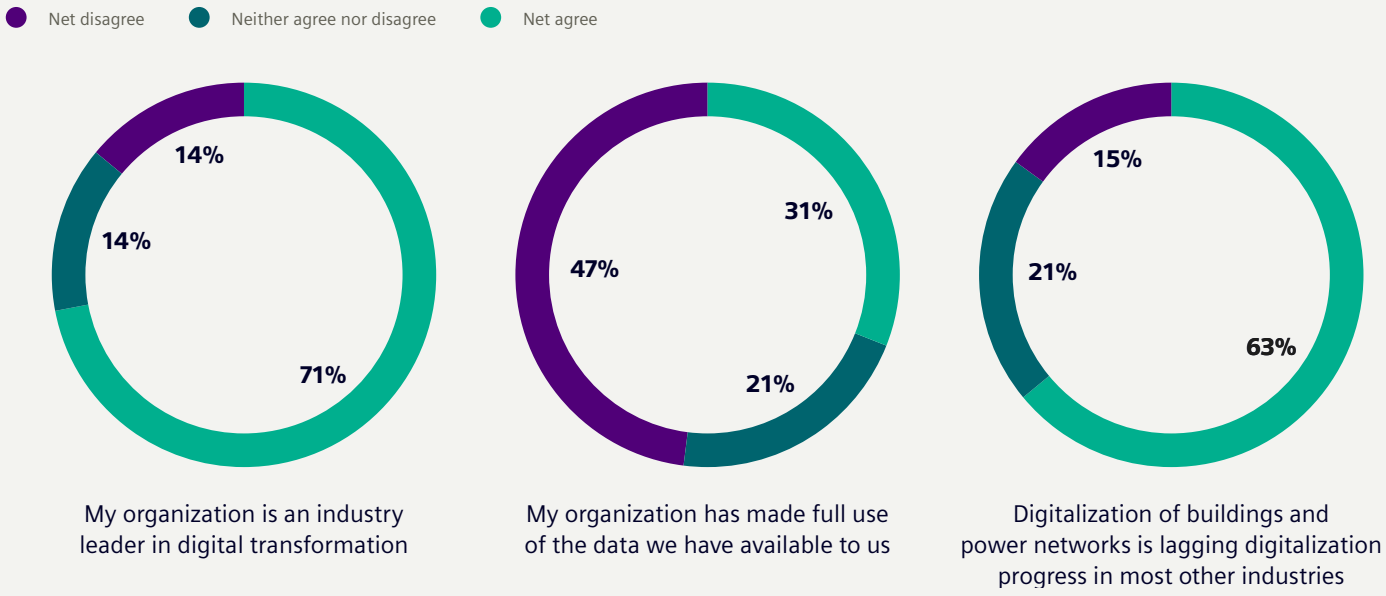
More value in data

Across the world of infrastructure much of the digital transformation journey still lies ahead.

While 71% of all respondents to our survey believe their organization is an industry leader in digital transformation, this needs to be set in context.

63% believe that the digitalization of buildings and power networks is lagging behind the progress of digitalization in most other industries (see **Fig. 2.2**)

Fig 2.2 Space for data-driven progress



Digitalization of buildings and power networks lags other industries, leaving a lot of space for progress on data-driven strategies and operations. [Percentages indicate the proportion that selected agree or strongly agree. Asked of all respondents (n=501). Those selecting "don't know/not applicable" are not shown, and as a result, percentages will not always sum to 100%.]

Being industry-leading in an infrastructure sector, may unfortunately still be short of current best practice.

Digitally advanced organizations are data-driven, and it is therefore of more specific concern that only 31% of our respondents appear to have made full use of the data they have, with nearly half reporting that they have not yet done so.

"The industry has a lot of data. It is shown on dashboards, but unfortunately there is often no action taken that will lead to a better return on investment, more sustainable operations, or any other benefit," says Ali Alsuwaidi, vice-president of the Middle East Facilities Management Association, an organization dedicated to best practice in the facilities management industry.

Many organizations that own two or more comparable assets have still not yet used comparative data to diagnose problems and optimize systems. The new digital space race will change this.

Progress relies on better benchmarks

Making more of internal data like this may rely on many things, but one is access to wider datasets that provide points of comparison. “If you only have data from one building, you cannot really take proactive actions,” says Alsuwaidi. “You need relevant benchmarks. You need data from other buildings with similar operational parameters to help us make the right decisions and help to understand the issues. Is it a skill problem, a design issue, an operational issue, the surrounding environment? There are a lot of variables. Right now, we have a lot of information, but too often it is being used in isolation.”

Part of the problem is that buildings have different owners, and data-sharing between them is sometimes – rightly or wrongly – prohibited by policies. But many organizations that own two or more comparable assets have still not yet used comparative data to diagnose problems and optimize systems. The new digital space race will change this.

“We want to get knowledge about how our tenants are using buildings to make the next building even better,” says Christian Waglechner, senior development manager at CA Immobilien Anlagen, an Austrian real estate company operating in several European countries. “We should not just implement 3,000 sensors to monitor one building. We should also do it to compare that data to other buildings inside our portfolio, and then outside, in similar locations.”

> We want to get knowledge about how our tenants are using buildings to make the next building even better.
>
> **Christian Waglechner**
> Senior development manager at CA Immobilien Anlagen, an Austrian real estate company operating in several European countries

Drawing from the full toolbox

In terms of specific technologies, AI-driven prediction and automation is expected to have the broadest impact on infrastructure assets over the next five years.

New materials is a close second, and several others – from blockchain to digital twins – make the top three for at least a quarter of respondents (see **Fig. 2.3**).

These specific breakthrough technologies or advanced methods are, like the tools of a carpenter, not as impressive in isolation, as the functional creations that can be made by using them together. The truly transformative power comes when organizations pursue important infrastructure goals with access to the whole, maturing, digital toolbox.

Digital twins are an interesting example because they draw together many different technologies to produce tools that help us overcome a diverse range of challenges at once. They are a powerful way to integrate siloed datasets, help us visualize vast amounts of abstract information, they enhance real-time monitoring, improve resilience, and support infinite simulations of possible future scenarios.

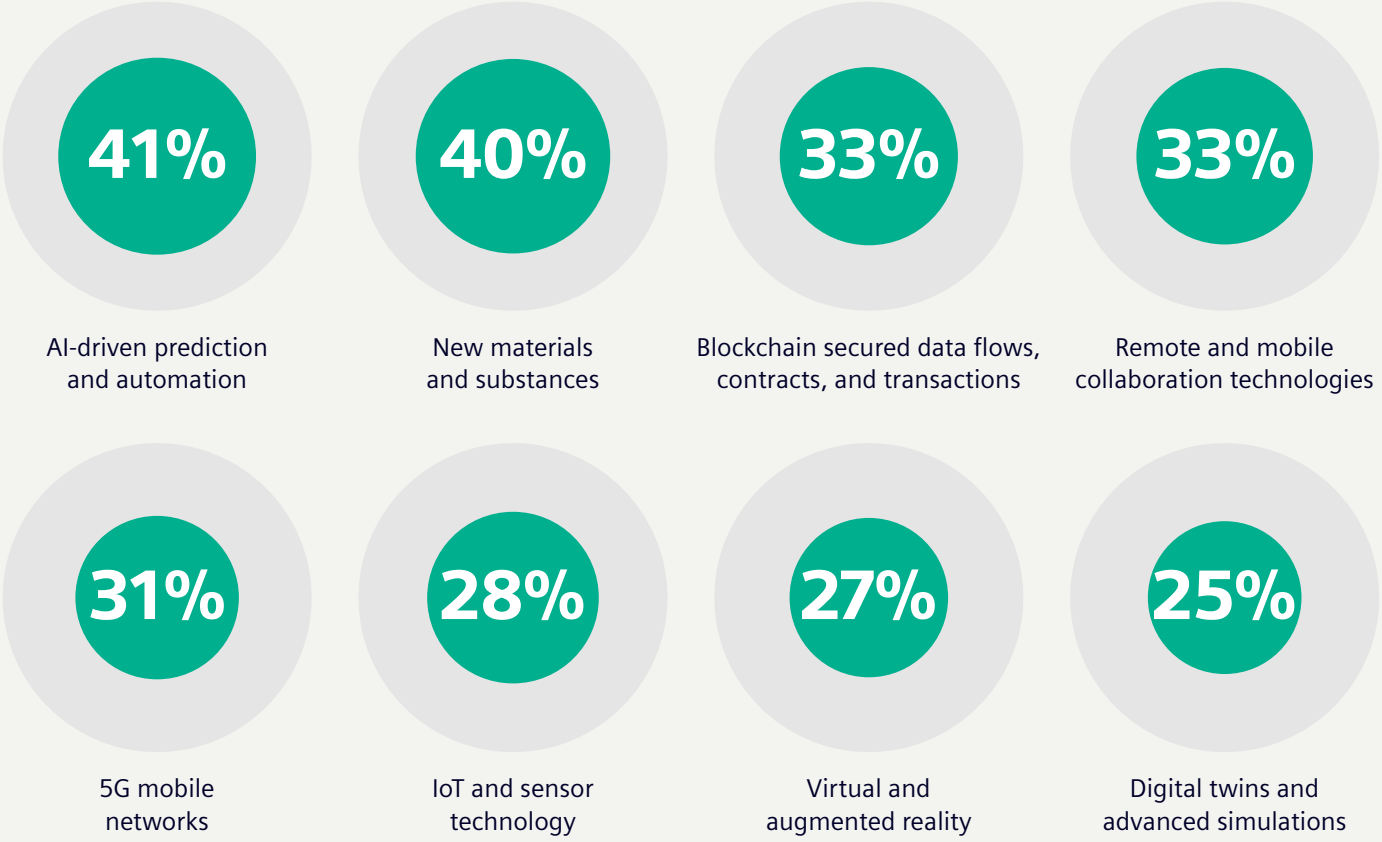
Digital twins can also be created to emulate any type of infrastructure asset – from a small factory to a giant power grid – and can also unify multiple infrastructure types, creating digital twins of whole cities and even national and international infrastructure systems.

"In the last two years, digital twins of cities have become much more important in the management of infrastructure management and urban planning," says Velegrinis, "I think we will start to see entire city digital twins really becoming the preferred tool for urban planning at the city and even national level in the coming years."

I think we will start to see entire city digital twins really becoming the preferred tool for urban planning at the city and even national level in the coming years.

Steven Velegrinis
Head of Masterplanning at AECOM

Fig 2.3 Deep impact: AI-driven prediction and automation



AI-driven prediction and automation expected to have the biggest impact on infrastructure assets, projects, or investments over the next five years. [Respondents could choose up to three technologies from a list of 10 (top eight shown). Asked of all respondents (n=501).]

The innovation mindset

This process never stops. Even the most advanced digital twins will be extended or enhanced by layering on further innovations or a technology from another domain. Velegrinis describes a case in point: "Digital twins are now being extended using things like game rendering engines, Unreal Engine for example, to create a full digital model of a city that people can experience with virtual reality from anywhere in the world."

Developing our digital solutions in this way relies on an innovation mindset within organizations. This can be a challenge of its own. "It is often a risk to change, and not everybody likes to be an entrepreneur or an innovator," says Waglechner. "Sometimes people only think about what has been done before, not about developing something new. But making progress requires us to do something new, it always has."

SECTION 3

A New Earth **Space** Race

The impact of physical and digital space on the planet as a whole, including a revolution in energy systems that will create a sustainable legacy for future generations.

Imagine you had the power to determine the future performance of your organization's infrastructure assets across four key priorities:

A. Significantly improved cost efficiency

B. Improved resilience to physical and digital threats

C. Significantly lower environmental impact

D. Reliable energy supply

But your choices are not going to be easy – you will need to compromise some to elevate others. For each of these priorities you must select only one of the following outcomes, and each can only be used once:

1. Guaranteed today

2. No short-term progress, but guaranteed in exactly three years

3. A 50:50 chance of success/failure every year

4. No progress for five years

Take a moment to decide what you would do, how you would match priorities with outcomes. Which priority would you like to be 'guaranteed today'? Which would you leave to chance? Where would you be willing to delay progress?

Leaders prioritize the environment

We put this scenario to our survey respondents and recorded their decisions. While, in reality, organizations are not faced with such exclusive, absolute options, responses to this dilemma can help us understand where the trade-offs are likely to be made in real, more nuanced, decisions over infrastructure strategy.

The standout finding from this scenario is the extent to which respondents prioritized significantly lowering their environmental impact. It was the most popular pairing with “guaranteed today” and the least commonly combined with "no progress for five years".[1]

Environmental impact was prioritized ahead of business fundamentals like costs, resilience, and reliable energy supply.

Cast your mind back just two or three years and it is hard to imagine that environmental impact would have been prioritized in this way, ahead of business fundamentals like costs, resilience, and reliable energy supply.

Shifting to low carbon infrastructure

“The energy transition is upon us. It has already started, and the trajectory is irreversible,” says Michael Webber, Josey Centennial Professor in Energy Resources, Mechanical Engineering at The University of Texas at Austin and former chief science and technology officer at ENGIE, a multinational energy company. Webber believes many governments and companies have now updated their legacy ideas about energy. While a few still cling to old ideas, “most have realized that the world of energy is already moving,” he says.

A similar shift is evident in other infrastructure domains. “We have seen a sea change around environmental issues in the last couple of years,” says Jeremy Kelly, Research Director at JLL, a global real estate services firm, “it was happening before COVID, but I believe the pandemic has brought the fragility of our society and environment to the forefront. There is a recognition that climate risk is financial risk. And so we have seen a sharp increase in demand for guidance on how clients navigate their decarbonization journey and deal with climate change.”

1 “Improved resilience to physical and digital threats” was the most popular pairing with “No progress for five years”, while “Reliable energy supply” was the most common pairing with “A 50:50 chance of success/failure every year”.

Climate risk has indeed become a financial risk, and also a risk to resilience (due to increased extreme weather and rising sea levels) and potentially reliable energy supply (as the world accelerates into a more distributed, complex energy system). This broader appreciation of environmental impact helps to explain why many respondents have put it ahead of other priorities.

The public sector has a special concern around resilience, particularly in regions that already have their share of extreme weather. “Governments are responding to climate change risk, and city resilience has become an automatic consideration,” says Steven Velegrinis, Head of Masterplanning at AECOM, a multinational engineering firm. “There was a time where everyone thought it was someone else's problem, but now people accept the reality, and are trying to mitigate the impacts.”

> “Governments are responding to climate change risk, and city resilience has become an automatic consideration.
>
> **Steven Velegrinis**
> Head of Masterplanning at AECOM

Velegrinis is based in Dubai, where leaders are concerned that 50°C days could quite soon become 60°C days, creating unlivable regions. There are bigger threats too: “If the long-term sea level rises occur, as per some of the IPCC forecasts, Dubai could lose two thirds of the city, without even considering the impact of storm surges,” he says.

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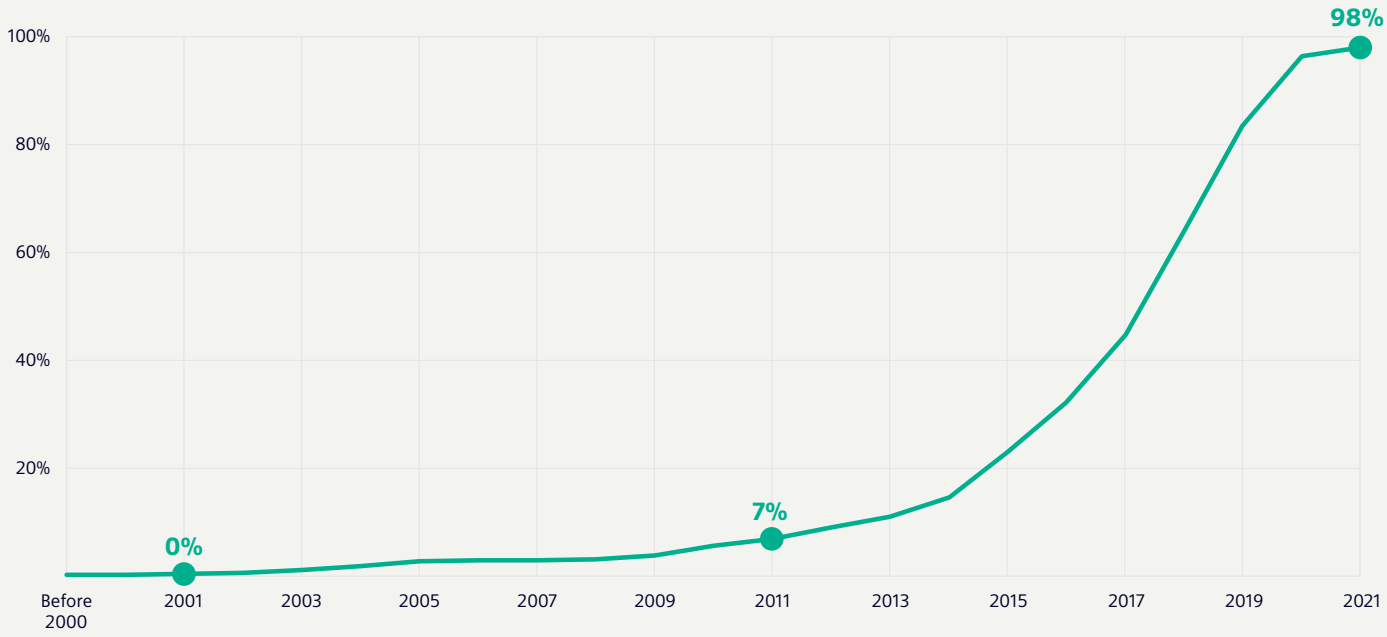
The target revolution

Over the past five years there has been an exponential rise in the number of organizations setting low-carbon or net-zero targets (**see Fig. 3.1**). There is also a lot of optimism around achieving these goals, with most of our survey respondents expecting their organization to be carbon neutral by 2030 (see **Fig. 3.2**).

The challenge will be turning this optimism into reality. "Whilst it's great to have a target, I think there is a bit of a gap at this stage, between the ambition and a clear strategy that gets you there," says Wayne Butcher, director at Grant Thornton, a global tax, accounting, and consultancy business. "It is only recently that organizations have started to fill in the details, and there is a need to really focus on the smaller steps now, to work out all the technical specifics and determine how operational models will work in a net-zero framework."

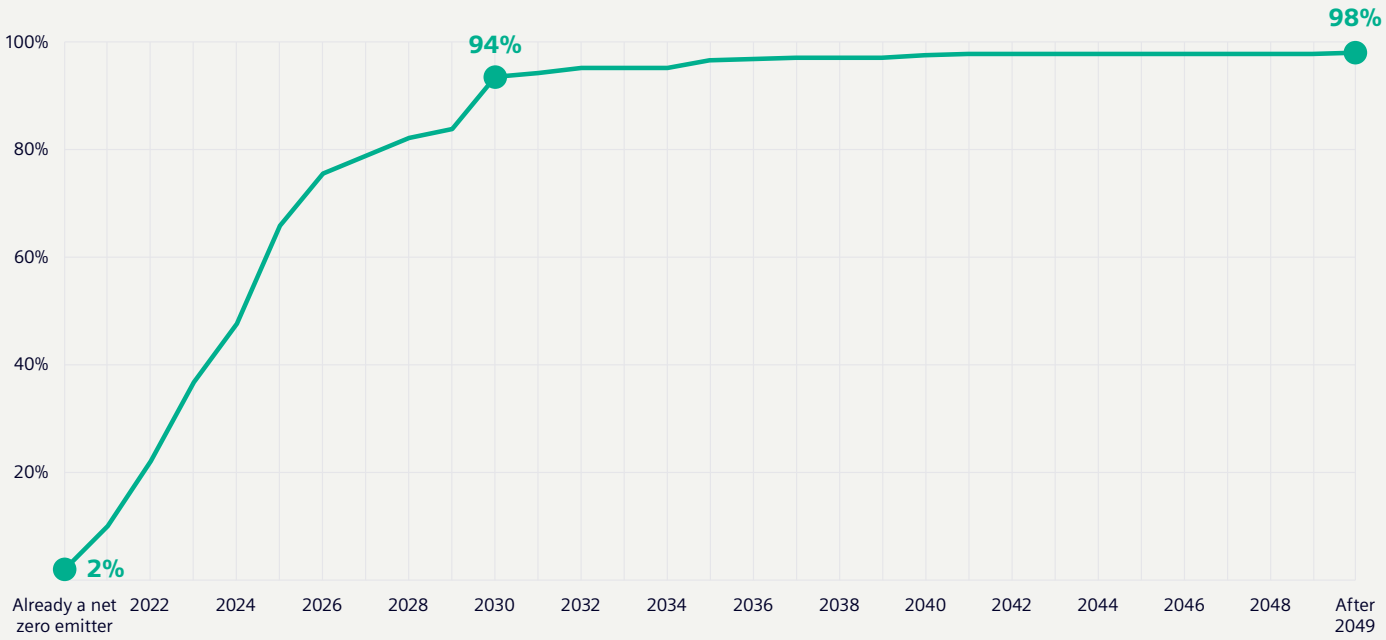
Energy produces three quarters of global greenhouse gas emissions, making clean energy the biggest priority of all in the fight against climate change. While there has been rapid progress in wind and solar, the energy transition has only just begun and needs multiple sources, technologies, and methods – with different mixes tailored to different regions and applications.

Fig 3.1 The exponential growth of low-carbon or net zero targets



Only 15% of respondents had targets in place before 2015. [Respondents were asked which year respondent organizations first adopted significant low-carbon or net zero targets. Asked of all respondents (n=501).]

Fig 3.2 The rapid shift to net zero



Two thirds (66%) of respondents said their organization would be a net zero contributor to global carbon emissions in (or before) the year 2025. [Asked of all respondents (n=501)]

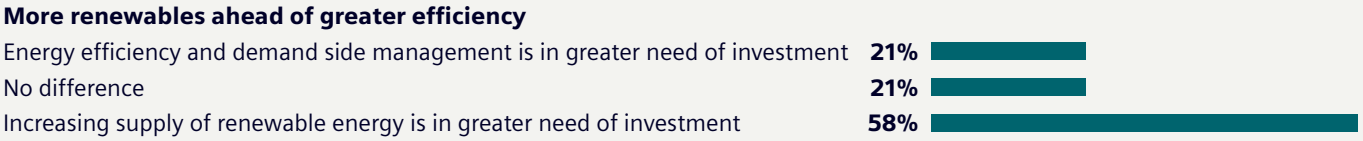
Energy storage is a key priority

Take energy storage for example. Most energy industry respondents (82%) believe energy storage systems for homes and businesses will be a critical part of the energy transition. Plus, the same respondents rated "energy storage systems to reduce wasted energy and improve resilience" as the highest priority among a set of potential strategy recommendations for cities.

Like the diverse range of energy generation technologies, there are a growing number of storage methods that will support the energy transition, including batteries, supercapacitors, pumped hydro, fly wheels, hydrogen electrolysis, and many thermal solutions, from hot rocks to chilled water.

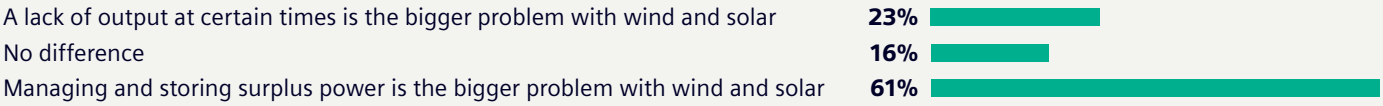
"Storage helps energy companies to use their capital and assets more efficiently," says Webber, "For example, underutilization is a fundamental problem for the power sector. In the United States we have about $5 trillion worth of power plants, transmission and distribution systems, that we use 45% of the time. Energy storage could reduce the need for some of these plants, while the remaining ones could work at closer to 80% utilization."

Fig 3.3 More renewables ahead of greater efficiency



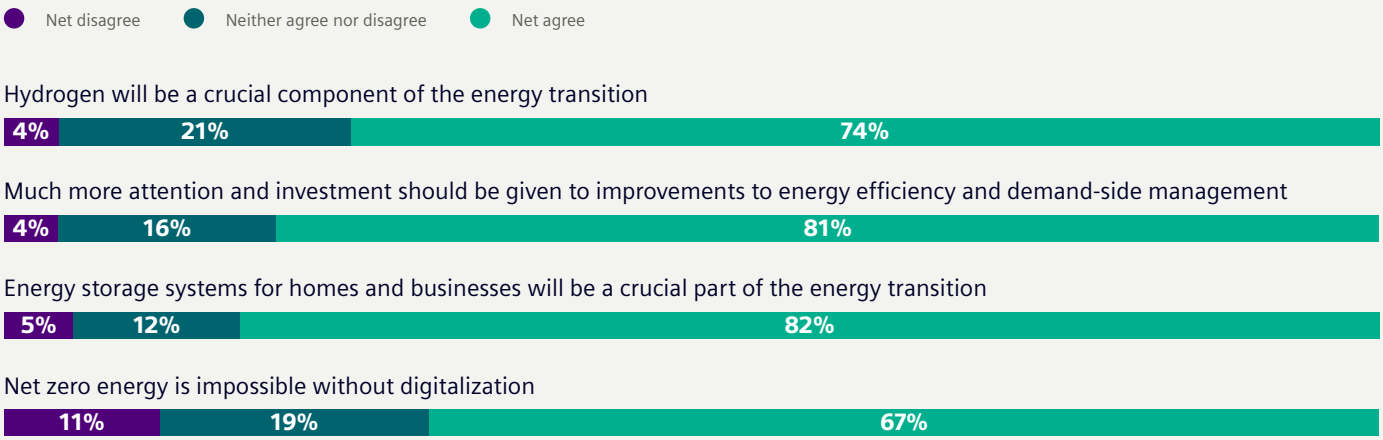
In this narrow choice, energy respondents favor investment in renewable energy generation. This reflects the vast scale of the energy transition, not a lack of focus on demand-side management, which is near-universally deemed important by the same respondents. [Asked only of energy respondents (n=57). “Don’t know/not applicable” was also an option; none selected this.]

Fig 3.4 Surplus power more challenging than erratic output



When renewables generate surplus power there are three options: use it, store it, or waste it. Many wind and solar installations are forced to waste potential green energy because of a lack of suitable transmission networks or storage options. [Asked only of energy respondents (n=57). “Don’t know/not applicable” was also an option; none selected this.]

Fig 3.5 Energy storage and hydrogen: crucial parts of the energy transition



Hydrogen is expensive, somewhat difficult to distribute, and is often an inefficient energy carrier compared to electricity. However, it is compelling as it has the potential to solve two major energy transition challenges: decarbonizing fuels and storing renewable energy. [Percentages indicate the proportion that selected agree or strongly agree. All respondents answered the top two statements (n=501). The bottom two were only put to energy respondents (n=57). Those selecting "don’t know/not applicable" are not shown, and as a result, percentages will not always sum to 100%.]

Integration challenges

Solar and wind energy present challenges for energy companies too, most notably in matching supply and demand.

If conditions are not suitable (e.g. at night, or when the air is still) then power generation may not meet demand. However, when demand is low, but it is sunny or windy, too much power may be generated. In these cases, the energy is often "curtailed" (effectively wasted) to avoid damage to the grid.

Energy respondents see the latter scenario (managing and storing surplus power) as a much bigger challenge than the former (a lack of output at certain times). This is certainly the case in Germany, where wind farms in the North generate large amounts of excess power, but this cannot be directed to the power-hungry South because the transmission network is not strong enough.

"In the North of Germany, renewables generate five or six times more than local load," says Xiaohu Tao, Vice President, Business Innovation and Digital, in Energy Networks at E.ON. "Connecting renewables to the grid is not a new challenge for us at lower voltage, but the high voltage connections needed to integrate those wind farms is much more challenging."

A key reason for this is that there is public opposition to construction of the new transmission lines that would be required to link the regions. The planning process takes many years, in some cases more than 10 years, and so Tao expects more political support will be needed. "To really accelerate network expansion, planning and approval processes must be consistently digitized, nature conservation requirements standardized, and sufficient manpower and technical resources made available for the approval authorities," he says.

Today, when power can't be used locally, or sold to neighbouring countries, it gets curtailed. This is not just a waste of clean energy; it comes with a significant financial sting. "Compensation is paid to the renewable energy companies that have to curtail power, and this is currently close to one billion Euro each year in Germany alone – it is an absolute waste that many are trying to change," says Tao.

Consumption without benefit

Smart grids, smart meters and other digital enablers will help us manage the complexity of clean energy supply, including the integration of distributed, multi-modal power generators and storage systems.

But much can also be done at the point of consumption. Demand-side management will be another critical piece of the energy transition puzzle. So much energy is wasted out of negligence. Insulation is lacking, devices are left on, blinds

are not pulled, machines are not updated – there are countless examples of energy that gets consumed without benefiting anyone.

Several principles can be used to help us get smarter about energy demand, including conservation, efficiency, penalties, incentives, scheduling and optimization. Digital systems deploying artificial intelligence, fuzzy logic, and various computational models are increasingly helpful as organizations aim to implement models built on these principles. They can make the quick decisions – based on huge sets of data – that are required to drive many demand-side management techniques.

The gigantic scale of the energy transition

Research in the US concluded that demand-side strategies could help to avoid about one fifth of annual electricity use in 2030.

It may seem surprising, in light of this, that in a binary choice, three times as many energy respondents said the supply of renewable energy needs greater investment than energy efficiency and demand side management.

But this finding does not mean that efficiency measures are not important. Away from that binary choice, an overwhelming majority of all respondents (81%) believe much more attention and investment should be given to improvements to energy efficiency and demand side management. The lop-sided result of that binary question reflects something else: an appreciation of the enormous scale of the energy decarbonization challenge.

81% believe much more attention and investment should be given to improvements to energy efficiency and demand side management.

Renewable sources are expected to reach 30% of total world electricity generation in 2021. This represents major progress – faster than many had expected – but electricity itself still only accounts for about 20% of total energy consumption. The balance of electricity generation – and the balance of total energy consumption – is dominated by oil, coal and natural gas.

Fueling the future

Many believe that the biggest challenge we all face in the race against climate change is in those areas that are hardest to electrify. “The vexing problem for the world isn't efficiency, or smart grids, or electrification – those areas are the easy part,” says Webber, “the hard part is how to decarbonize fuels, how to develop viable green gasses that work at scale and within viable business models.” Many of the world’s most energy-intensive processes, in heavy industry and heavy transport, do not yet have viable electrical alternatives to combusting fuels.

> The hard part is how to decarbonize fuels, how to develop viable green gasses that work at scale and within viable business models.
>
> **Michael Webber**
> Josey Centennial Professor in Energy Resources, University of Texas at Austin

This is perhaps why “hydrogen infrastructure rollout” was the second highest strategic priority for cities among energy respondents. Green hydrogen (i.e. hydrogen made from the electrolysis of water using renewable energy) could be the green gas of the future.

However, green hydrogen is currently too expensive for most large-scale applications, and a functioning green hydrogen economy will require a vast expansion of renewable energy capacity and supporting infrastructure. It will take an estimated US$70 billion to develop a competitive hydrogen economy by 2030.

Despite this, most in our survey are optimistic about the gas, with three quarters (74%) saying that hydrogen will be a crucial component of the energy transition.

Hydrogen is also compelling because it can be used for energy storage, turning what would have been curtailed renewable energy into a transportable green energy commodity. It is no surprise then that five German states in the country’s north have kicked-off a joint plan to transform the region into Europe’s leading area for hydrogen production.

The hard carbon problem

The decarbonization of fuels is related to another big challenge of the new earth space race. Infrastructure leaders can decarbonize the energy used to operate buildings and other assets, but there is a deeper challenge to solve: "There is a lot of embodied carbon in the basic bones of a building, the structure, including the concrete and steel of the frame and foundations," says Ewan Jones, partner at Grimshaw, a global architecture practice. "There is now a bigger focus on this, measuring and reducing the embodied carbon, and not just emissions from operations."

There is a lot of embodied carbon in the basic bones of a building, the structure, including the concrete and steel of the frame and foundations.

Ewan Jones
partner at Grimshaw

This is related to the fuels problem because manufacturing, processing and transporting things like steel and cement, are exactly the kind of hard-to-electrify applications that are difficult to decarbonize. In our survey, respondents rated new materials and substances as the innovation or technology they expected to have the second biggest impact in the next five years (after only AI-driven prediction and automation). This could be part of the solution to reducing embedded carbon in new buildings.

Cross-laminated timber (CLT) is one example. Some believe CLT has great potential as a more sustainable building material than steel and concrete. Research indicates that if made from sustainable forestry sources, CLT stores enough carbon within it to offset the emissions released from its production, making it a net negative carbon emitter. Embodied carbon is also a factor in decisions about whether existing buildings are refitted and reused, as opposed to being demolished and rebuilt. Retrofitting saves much of the carbon that would be needed for new construction, while often also improving operational efficiency and environmental performance.

"It is estimated that 40% of all emissions are from real estate, and about one quarter of that is in the form of embedded carbon, used in the materials and construction process," says Kelly, "recognition of the retrofitting challenge will force greater collaboration." As Kelly points out, however, the challenge is that retrofitting is not easy, "and the construction industry, in general, has not yet solved the puzzle of how to effectively retrofit aging stock," he says.

Carbon cooperation

Decarbonization will rely on a great deal of combined effort on the part of all infrastructure and energy stakeholders. This is accepted by the vast majority in our survey, with over eight-in-ten (82%) saying increased cooperation and coordination between diverse stakeholders is crucial to reducing CO2 emissions from energy and infrastructure.

82% say increased cooperation and coordination between diverse stakeholders is crucial to reducing CO2 emissions from energy and infrastructure

"Net zero will not happen if we do not cooperate together," says Tao, "These are joint issues that impact everyone. Energy stakeholders should be innovating, sharing ideas and working together, because it is the most challenging and important issue for us all."

Part of this will rely on strong leadership and support from the most powerful players because regions and organizations are of course at different stages on the journey to dealing with climate change, building resilience and decarbonizing their assets and operations.

"Some of our clients are major corporations and institutional investors who have strong commitments to green standards, in terms of their buildings, operations, and supply chains," says Kelly. "But there is a very long tail of businesses that are pretty early on in their decarbonization journey. They often have some level of commitment, but often lack the resources or know-how to implement a strategy."

Greater cooperation can play a role in making decarbonization both a universal imperative and a practical reality.

The urgent transformation of infrastructure across our three dimensions – the physical, digital and earth spaces – is a race with the urgency of a sprint, but the duration of a marathon.

Infrastructure transformation: a race with the urgency of a sprint, but the duration of a marathon…

Infrastructure stakeholders need to make difficult trade-offs along the road, much like in the dilemma at the start of this chapter. Of all the priorities that need to be weighed, decarbonization is increasingly the one with the biggest influence on the scales. It will be among the most powerful drivers of change in physical spaces, while the maturation of digital space will be a primary enabler of change in the earth space.

This is just one of many ways in which the three space races are one, with aspects of physical, digital and earth spaces acting simultaneously as both drivers and enablers of change. This is the nature of the new space race – a race of unified human, digital and environmental priorities, and a race we must all strive to win together.

Interviewees and acknowledgments

We would like to extend a special thank you to the diverse set of industry leaders and experts who shared their ideas and insights with us as part of this study.

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Jeremy Kelly
Research Director at JLL, *a global real estate services firm*

Dr. Kerstin Sailer
Co-Founder of Brainybirdz and Professor in the Sociology of Architecture at the Bartlett School of Architecture, University College London

Maia Small
Manager, policies and strategies at San Francisco Planning

Steven Velegrinis
Head of Masterplanning at AECOM, *a multinational engineering firm*

Christian Waglechner
Senior development manager at CA Immobilien Anlagen AG (CA Immo, *a European commercial real estate company*)

Michael Webber
Josey Centennial Professor in energy resources, mechanical engineering at the University of Texas at Austin

Dr. Tao Xiaohu
Vice President, Business Innovation and Digital, in Energy Networks at E.ON, *a European electric power company*

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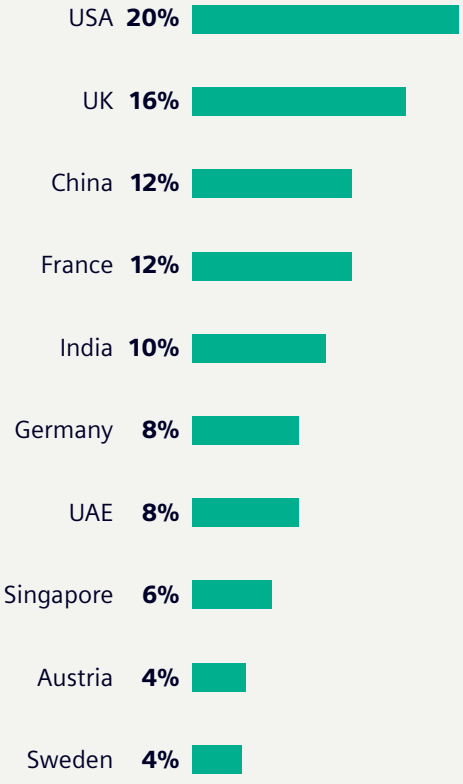
Head of Sustainability

Emma Falck
Head of Strategy

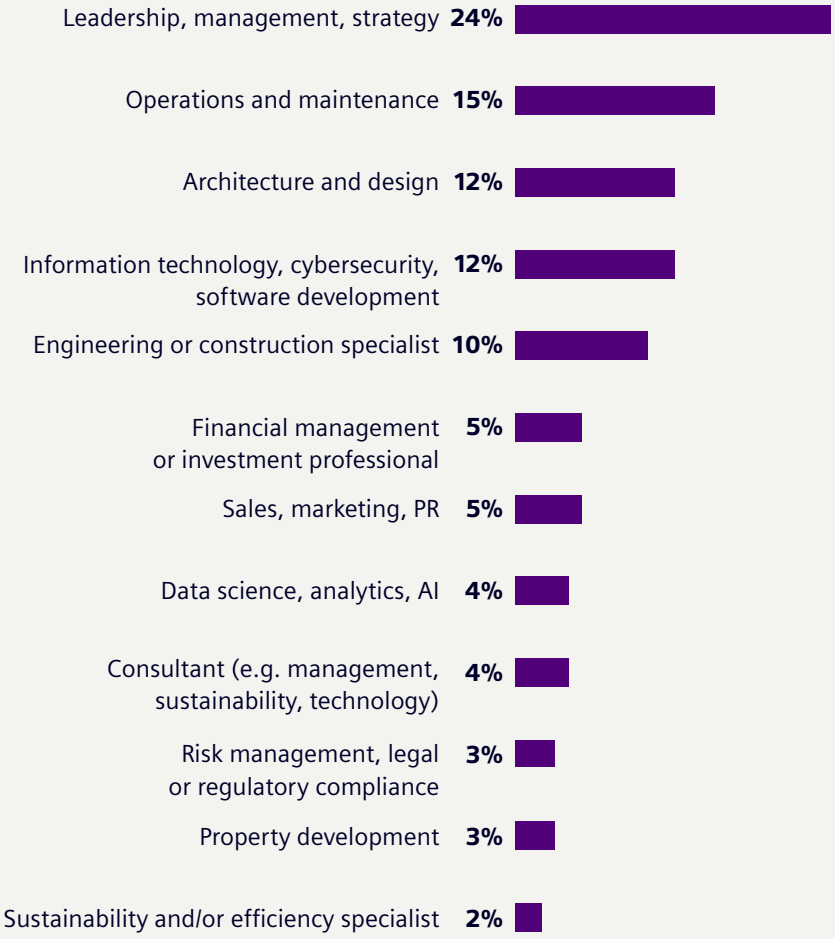
Methodology

The survey included 501 respondents from 10 countries. The countries involved include those large-scale and/or highly advanced infrastructure assets and ambitions. It was fielded in June and July 2021.

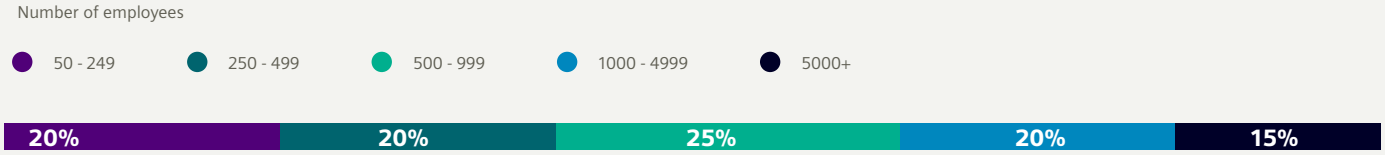
Countries involved



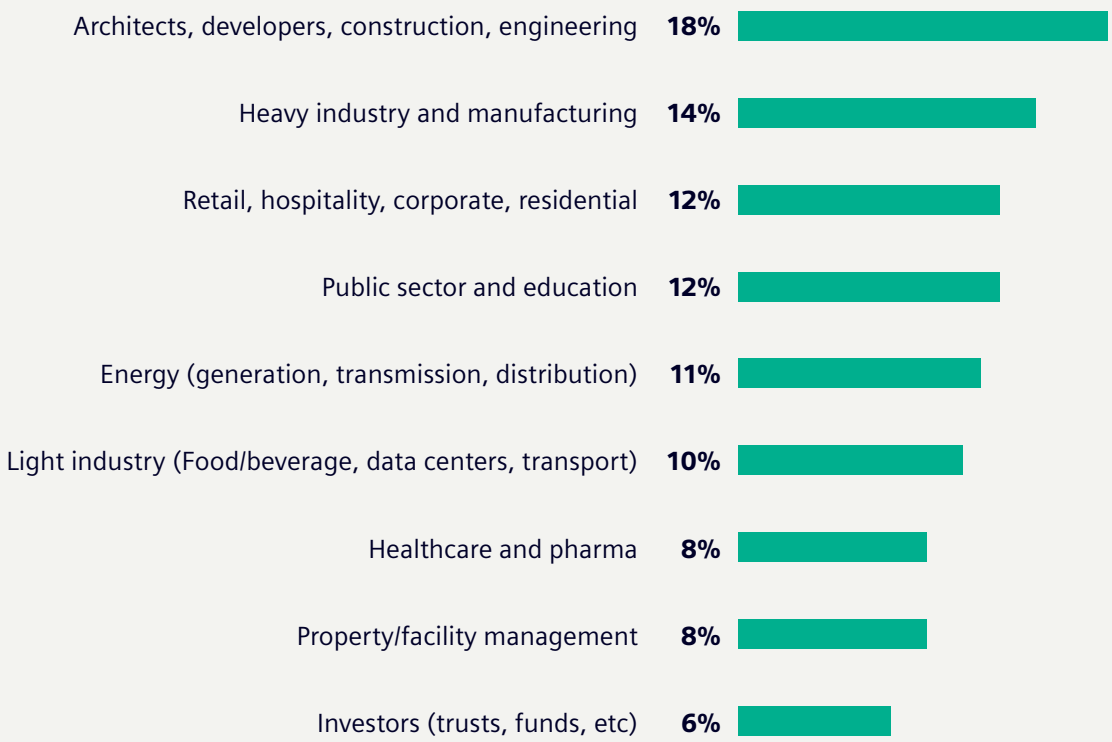
Primary role



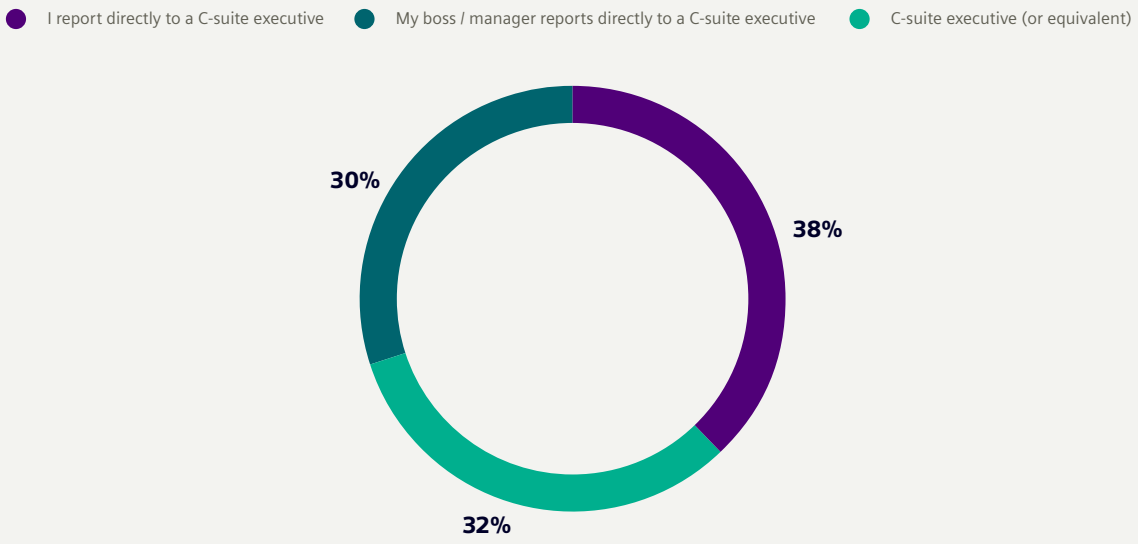
Organization size



Industry



Seniority



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Smart Infrastructure intelligently connects energy systems, buildings and industries to adapt and evolve the way we live and work.

We work together with customers and partners to create an ecosystem that intuitively responds to the needs of people and helps customers to better use resources.

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