

SIEMENS INFRASTRUCTURE TRANSITION MONITOR 2023

The great divide on the path to net zero

How divisive issues and different pathways threaten the speed, scalability, and efficiency of the infrastructure transition



SIEMENS

Mission statement

The Siemens Infrastructure Transition Monitor explores the state of the infrastructure transition, the urgent priorities, and the path ahead for business and government leaders, who must work together to responsibly evolve the world's infrastructure.

The Monitor was developed to inspire greater and faster real-world impact in the modernization, expansion, and decarbonization of **energy, buildings, mobility, and industries**.

The program also emphasizes innovation. Constructing and operating the next generation of infrastructure will be enabled by the world's best technologies, data-driven strategies, and hundreds of big ideas.

Within this context, the **Siemens Infrastructure Transition Monitor** advocates three imperatives:

1. Infrastructure transition must make a positive impact beyond decarbonization.

The research is deliberately broad, recognizing that the world needs to reshape infrastructure, not only to **decarbonize energy systems and industrial operations**, but also to improve **resource efficiency** and deliver positive **socio-economic impacts**. Major infrastructure changes are an opportunity for progress in all these domains and so projects should target a broad set of goals.

2. Smarter infrastructure integration is mandatory.

With so much of the world set to change so fast we cannot afford to think, or act, in silos. There is a great need for joined-up strategies, idea sharing, and close coordination between governments and industries. Collaboration and innovative technology solutions will deliver **smarter integrations between the diverse elements of infrastructure** which underpin our world.

3. Top speed is the only acceptable pace for infrastructure transition.

Finally, the critical urgency of the infrastructure transition is what sets it apart from other megatrends that change the world. Never before have leaders – from communities, businesses, and government – shared such a great **collective responsibility to rapidly reshape the world** towards the same outcomes. This research reminds all of us that we have a profound need to act urgently to protect humanity and Earth's biodiversity.



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INTRODUCTION

What is the **great divide**?

All the countries, businesses, and citizens of the world entered this era of transition from different starting points, with unequal resources, diverse philosophies, and specific challenges. As a result, we now see many different transition speeds and pathways toward the cleaner, smarter infrastructure of the future.

The infrastructure transition also spans many dilemmas, divisive issues, and difficult decisions. There are several live debates about major choices, such as the feasibility of carbon capture and storage, the role of green and blue hydrogen, the best types of energy storage, the use of carbon pricing mechanisms, the role of biofuels and synthetic fuels, the level of government intervention, whether to build new or retrofit, how to change consumer behaviors, the potential of vehicle-to-grid systems, the economic cost of decarbonization – the list goes on.

Only half of senior executives believe their country has a consistent (52%) or effective (47%) decarbonization strategy

This research finds the world divided on many of these big issues, while a gulf has opened between the accelerating transitions of leading organizations and nations, and those that are far behind. Of course, different contexts and opinions are normal. And in more stable times, we could afford to absorb the resulting inefficiencies and delays. But today, the world cannot afford to be so divided.

“The infrastructure transition is urgent, and the consequences of delay are severe. To reverse, or at least slow down, global warming – and to make the world more resilient to climate change – we need to transform our infrastructure at unprecedented speed and scale. To do this, we need greater alignment, collaboration, and standardization,” says Matthias Rebellius, managing board member of Siemens AG and CEO of Smart Infrastructure.

On many of the infrastructure transition goals investigated in this research, we find similar numbers of respondents at both ends of the progress scale, which reveals many of the specific areas in which different speeds and pathways are in play. This is the case across each of the ‘Spheres’ of influence we explore: regions, cities, and industries.

What is the infrastructure transition?

The infrastructure transition describes a fundamental reshaping of the structures and systems that keep our world functioning, including the infrastructure that supports energy, buildings, mobility, and entire industries.

This transformation – unfolding between 2020 and 2050 – is arguably the largest, quickest, and most pervasive shift in the history of infrastructure development.

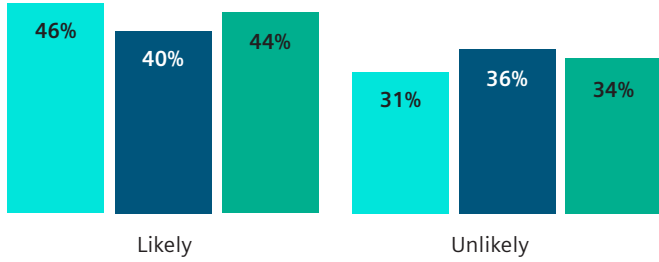
What is causing the infrastructure transition?

The energy transition and the decarbonization of industry are the primary catalysts for the infrastructure transition, but other megatrends have a strong, simultaneous influence, including digitalization, population growth, and demographic change.

There are also less predictable forces that evolve infrastructure needs and possibilities, such as technological breakthroughs, new regulations, economic cycles, social norms, and political change.

Respondents are also divided on the likelihood of decarbonization outcomes for their organizations:

- Accelerating decarbonization efforts in the year ahead
- Meeting decarbonization targets for this year
- Meeting decarbonization targets for 2030



Despite these splits on targets, we might hope to find common ground on the big issues. But this was not what we found. We asked respondents how well aligned and unified citizens, businesses and government are on seven major transition issues, from the need to accelerate decarbonization to ensuring energy supplies are secure and affordable. On average, the results found three distinct groups:

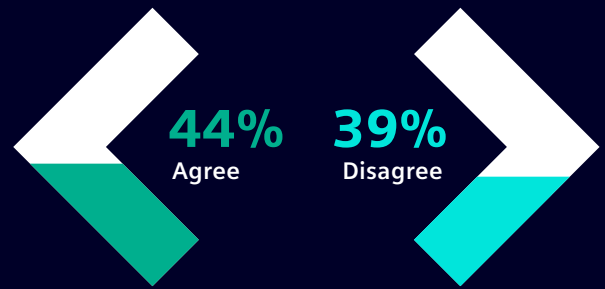


In many key areas – within industries, cities, countries, and regions – divided opinions and different contexts are a threat to the speed, scalability, and efficiency of the infrastructure transition. This report does not have all the answers, but we want to raise important questions and stimulate debate. By doing so, we hope to build greater consensus on which gaps matter most and how to start closing them.

Similar fragmentation was evident across many more specific issues we investigated. Many are highlighted throughout the report in this format:

A divide in transition?

My organization prioritizes finding the quickest way to decarbonize, ahead of cost or revenue implications





What are the 'Spheres'?

The three Spheres of this research refer to three domains of significant power and influence. Each has a different jurisdiction over, and a different perspective on, the infrastructure transition, but the issues, challenges, and opportunities of each Sphere are overlapping and interdependent.

In each Sphere we examine the current progress and future priorities for a set of core infrastructure transition goals. The infrastructure transition is truly a giant topic, so for this research we have selected a key focus area for each Sphere. In summary:

- Sphere 1 takes a regional perspective, exploring national and international issues. Energy is the key focus area in Sphere 1
- Sphere 2 takes a city perspective, investigating city governance and urban issues. Mobility is the key focus area in Sphere 2.
- Sphere 3 takes an industry perspective, examining commercial and sector-specific issues. Buildings are the key focus area in Sphere 3.

"About the research" on **page 43** has more details about the research, including definitions, acknowledgments, and the survey sample profile.

Why all the questions?

The infrastructure transition is a shift to a world that is gradually taking shape, not according to a master blueprint, but through a cycle of exploring possibilities, building strategically and adapting as we go. There are many challenging questions about what to do next, how best to do it, and what to expect. No single organization has all the answers. Reflecting this, all of the sub-headings in this report are questions to reflect the open, inquiring and collaborative approach we need to succeed in the infrastructure transition. Our intention is to start conversations, which could lead to ideas, which could lead to progress.





Sphere 1

THE REGIONAL PERSPECTIVE

**Energy alignment and the
regulation of change**

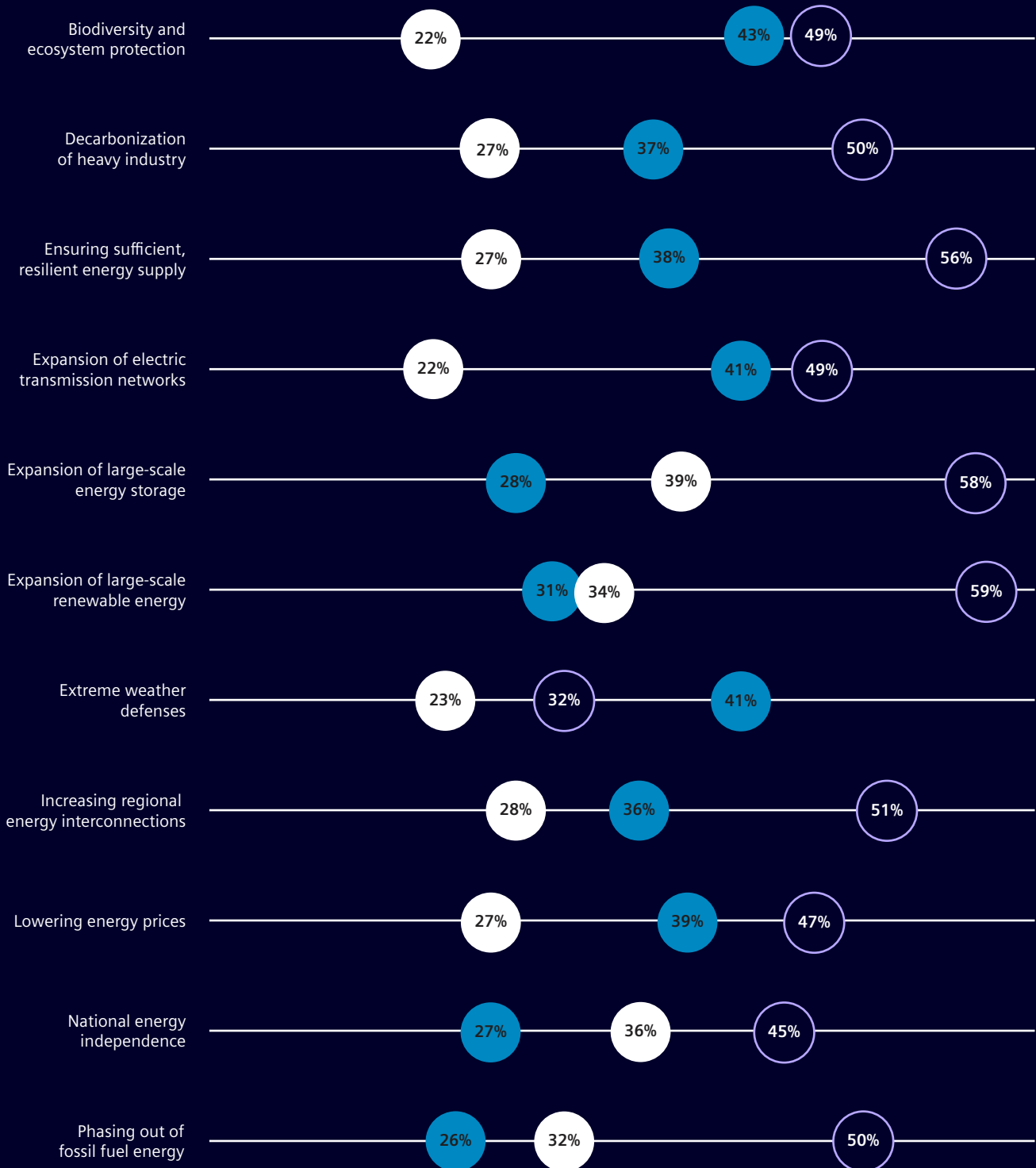


Only **half of senior executives** believe their country has a consistent (52%) or effective (47%) decarbonization strategy. Regulatory authorities, which implement and steer these strategies, are seen as having the greatest responsibility for advancing the infrastructure transition, but **can citizens, business, and government align behind a unified direction?** To explore these issues, the Regional Sphere zooms out for a big picture perspective on how countries and regions can accelerate the infrastructure transition.



Progress and priorities on infrastructure transition goals for regions

● Advanced/mature ● Planned (but undeveloped) ○ Budget priority



- **Biodiversity and ecosystem protection** is rated as the most developed area – **43%**
- But those measures are threatened by low progress on the phasing out of **fossil fuel energy** – **26%**

- While the **expansion of large-scale renewable energy** is among the least advanced, it has the highest overall priority for the year ahead – **59%**

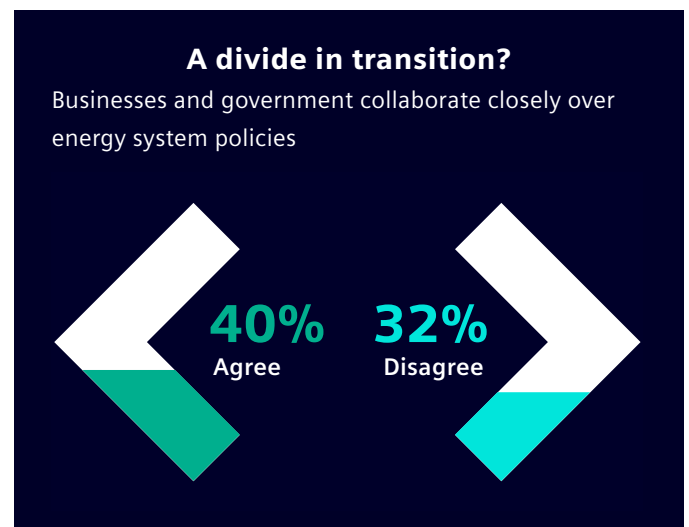
Which are the most important infrastructure **transition goals**?

The infrastructure transition is accelerating, despite the social, political, and economic challenges of recent years. And the pace of change is putting pressure on infrastructure systems worldwide. Countries and regions might be doing more than ever to reduce their reliance on fossil fuels, but despite some acceleration and straining infrastructure, change isn't happening fast enough to slow CO₂ emissions in line with Paris Agreement targets.

To support a low-carbon world, energy, transportation, water, waste, and digital infrastructure all need to transform – urgently. These infrastructure systems are all interconnected, but energy is the most pervasive and important: nearly three-quarters of global greenhouse gas emissions come from the production, use, and transportation of energy¹.

¹ <https://www.iea.org/reports/world-energy-outlook-2022>

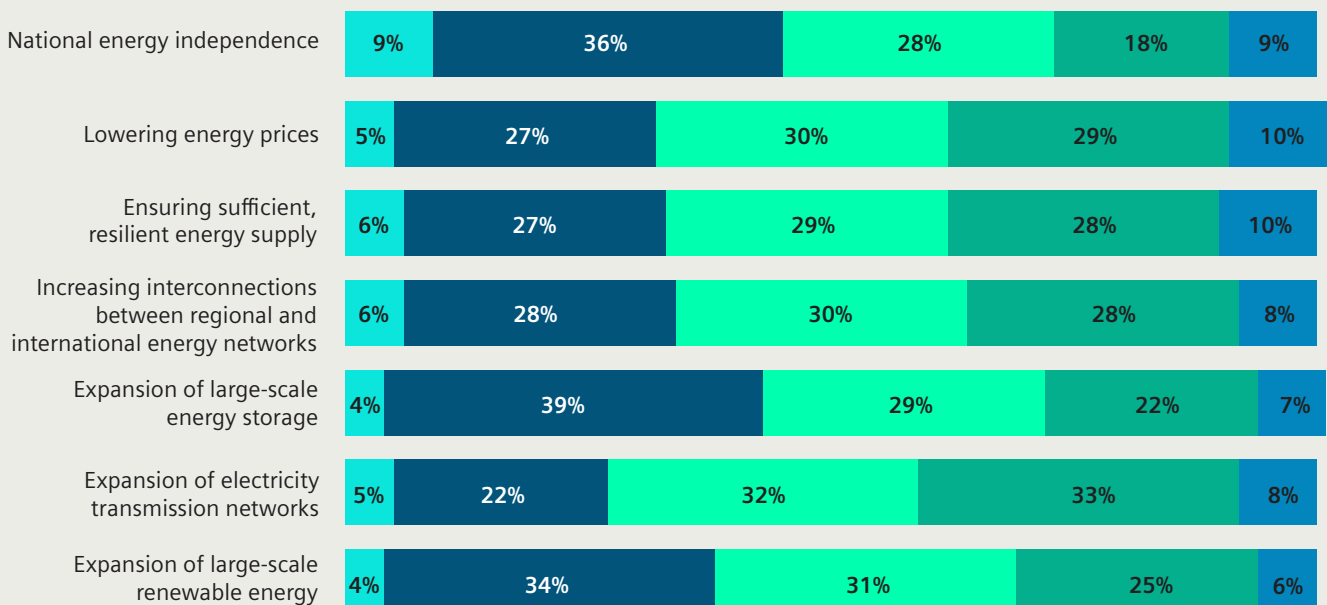
Very few of the executives we surveyed (10% or less) consider their region/country to be “advanced, fully integrated, full-scale” on the major energy goals of the infrastructure transition. Most (60%–70%) are either “emerging, isolated, small-scale” or less developed.



New energy system progress

Note: Percentages may not sum to exactly 100% due to rounding.

- No existing or planned activity
- Emerging, isolated, small-scale
- Advanced, fully integrated, full-scale
- Planned but undeveloped
- Maturing, semi-integrated, large-scale



Can we reach and maintain a fast enough **transition**?

To decarbonize the world's energy systems, we have to redevelop the infrastructure that supports it. This is a multi-decade, \$275 trillion shift requiring deep changes to electrical power generation, distribution, and consumption, as well as industrial processes, buildings, transport, and the governance, systems, and structures that keep the world functioning².

A major part of this is the rapid expansion of renewable energy assets, with a lot of this energy being generated remotely or in offshore areas. Connecting these new power plants requires new transmission lines and substations to interconnect with the existing grid. At the same time, smarter distribution grids are needed to maximize available capacity, manage demand, and turn passive energy consumers into adaptive prosumers (i.e., citizens and businesses that produce their own energy and sell their excess energy back to the grid).

"The pace of change is accelerating, and trends are developing faster than predicted," says Sabine Erlinghagen, CEO Grid Software at Siemens. "For instance, electric vehicle charging infrastructure, electric heat pumps, and other distributed energy resources are growing exponentially. In most countries, power grid infrastructure is at capacity and inadequate for this projected growth. This exponential growth puts significant pressure on infrastructure, which is

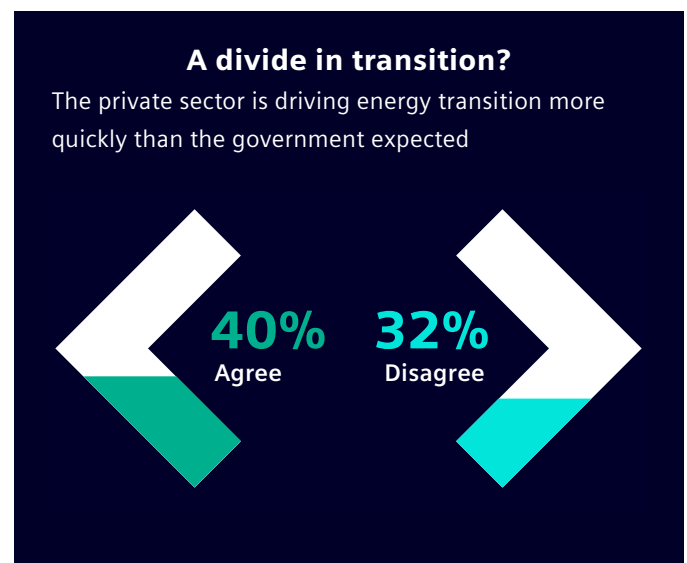
struggling to keep up with rising demand, leading to stress on organizations and the physical grid. There is a growing awareness of the challenge at hand, but we have to act faster and investigate innovative solutions."

This research finds relatively low progress on many infrastructure transition goals, which reflects how much more work there is to be done, particularly in key areas such as renewables, energy storage, and fossil fuel reduction. So to reach and maintain a fast enough transition, all stakeholders will likely need to adapt to a new reality of long-term accelerated change, with all the associated disruption and infrastructure strain. The urgency of the infrastructure transition makes this unavoidable.

The Intergovernmental Panel on Climate Change (IPCC) reports that every incremental rise in global temperatures will "intensify multiple and concurrent hazards," and the scenarios that limit warming to under 1.5°C or 2°C both require "rapid and deep and, in most cases, immediate greenhouse gas emissions reductions in all sectors this decade³."

² <https://www.mckinsey.com/featured-insights/sustainable-inclusive-growth/chart-of-the-day/the-cost-will-not-be-net-zero>

³ <https://www.ipcc.ch/report/ar6/syr/resources/spm-headline-statements>



Who's responsible for the infrastructure transition?

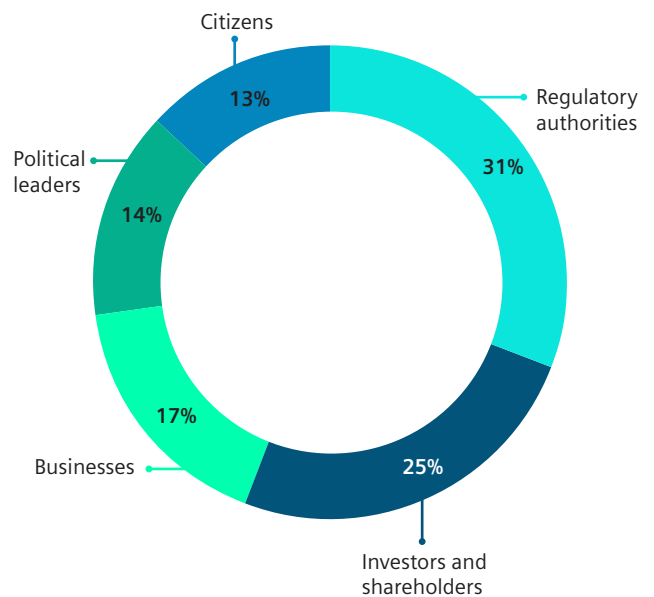
We're all responsible for the infrastructure transition, but some of us have more power to effect change than others. We asked our respondents to allocate percentages – between regulatory authorities, investors/shareholders, businesses, political leaders and citizens – to show how they believe responsibility should be shared for driving progress in the infrastructure transition.

Regulatory authorities (31%) are seen as having the greatest responsibility for advancing the infrastructure transition, followed by the ultimate owners of assets, investors/shareholders (25%). Businesses (17%), politicians (13%), and citizens (13%) all have some, but significantly less. This pattern is largely consistent across countries.

Regulators are in a tough position. Governments most often set their agenda, but political change can quite suddenly rearrange priorities. However, it is important that regulators give businesses stability and certainty around public policy because it encourages investment and maintains momentum in the infrastructure transition.

“Certainty in the market is important. Investors and businesses need to know what the rules are and how they will change over time,” says Cassie Sutherland, Managing Director, Climate Solutions and Networks at C40 Cities. “For example, the net zero carbon building code sets new requirements for energy demand in new buildings. These requirements can be ratcheted up over time, which gives the market time to prepare. This provides certainty and predictability, which encourages investment and innovation.”

How should responsibility be shared for driving progress in the infrastructure transition?

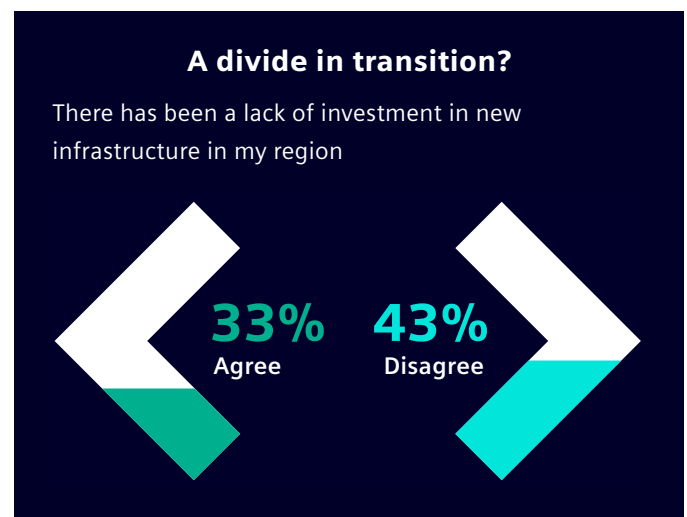


What do we want from regulators?

Regulators also need to build new frameworks to govern a changing and uncertain set of systems that are in various stages of implementation. Take the electricity market, for example. “The remuneration system still favors traditional timeframes and investment types,” says Sabine Erlinghagen. “There’s pressure on grid operators to change their purchasing and decision-making processes, but there’s no clear consensus on how to do this. Some operators are experimenting with a new approach, but this hasn’t yet become standard practice. New frameworks are needed from regulators that define remuneration models for various parts of the new energy system.”

It’s crucial, with so many stakeholders involved, that there’s a clear plan of action communicated to everybody, especially when it comes to the energy system and electricity grids. However, like with many aspects of the infrastructure transition today, there are competing ideas about what the plan should be, which technologies should be involved, and how systems should evolve.

“All stakeholders – businesses, utilities, homeowners – need to know what the plan is,” says Oliver Franz, Vice President of European Associations at E.ON. “When will we phase out gas appliances? Will we leave them in place and feed them with something else, like hydrogen? Or will we connect them to district heating? Having a plan will enable people to make informed investment decisions. This will help to avoid waste or delays and ensure a transition to a low-carbon future in a way that is fair and equitable for everyone.”



All stakeholders – businesses, utilities, homeowners – need to know what the plan is.

Oliver Franz

Vice President of European Associations at E.ON

Do we have to follow the **country next door?**

Globalization and cross-border integration create further challenges. The number of stakeholders multiplies every time a new country is factored into decisions that cross borders. For example, there is a major need to build electricity demand response systems for buildings, to help manage electricity demand during peak periods, enhance grid stability, and promote energy efficiency. However, developing specialized solutions for each country can hinder the speed and efficiency with which we roll out such programs.

More generally, there are several benefits that flow from the expansion – and greater use of – interconnections between electricity networks in different countries (or sub-national divisions). These include reliability, cost efficiencies, and in some cases, the ability to balance variations in renewable energy generation. However, greater use of grid interconnections also present challenges, including the need to align regulatory frameworks, coordinate operations and maintain grid security. Only 36% of those we surveyed said that their country or region was mature or advanced on the goal of increasing interconnections between regional and international energy networks.

Or consider the challenge of electrifying long-haul trucking in Europe. “Drivers in Europe are legally required to rest for 45 minutes every four hours,” says Franz. “So truck

manufacturers are being asked to develop electric trucks that can recharge within that timeframe. This probably means we need megawatt charging, which is challenging to implement because the charger equipment is bigger – both at recharging points and on the truck.”

Then factor in the fact that cross-border trucking is common in many parts of Europe. “This means that truck drivers need to be able to pre-book charging points in other countries,” says Franz. “If each country has its own booking system and charging standards, it won’t work. Instead, there needs to be a common data standard and some level of coordination between countries. I’m not a fan of excessive planning, but in this case some coordination is essential. Otherwise, it will be very difficult to electrify long-haul trucking in Europe in a way that’s efficient and cost-effective.”

Governments are making efforts to lay down supportive pathways to decarbonize energy and industry. Examples include the European Green Deal, the US Inflation Reduction Act, and China’s commitment to become carbon neutral by 2060. Ideally, these measures will help to drive the kind of coordination required for the infrastructure transition, but we still need organizations to agree about the specifics and align with both government and citizens about how to proceed.



Are citizens, businesses, and government aligned?

We asked respondents to our survey how much alignment and unity there is between citizens, businesses, and government on seven major aspects of the infrastructure transition. Only 38% indicated alignment and unity on the need to accelerate the rate of decarbonization, but no other area was any better aligned or unified – all recorded similar or lower levels.

One reason for this is that these groups have different priorities. Citizens are often supportive of the infrastructure transition until it impacts their immediate area – the not-in-my-backyard problem. Citizens are also often more interested in the immediate impacts of infrastructure transition, such as job losses and higher energy costs. Businesses, by contrast, are often more interested in the long-term economic impacts of infrastructure transition, such as the cost of new technologies and the need to adapt to a changing climate. And governments are more likely to be thinking about the overall public good, such as making sure the population has access to clean, affordable energy and transportation.

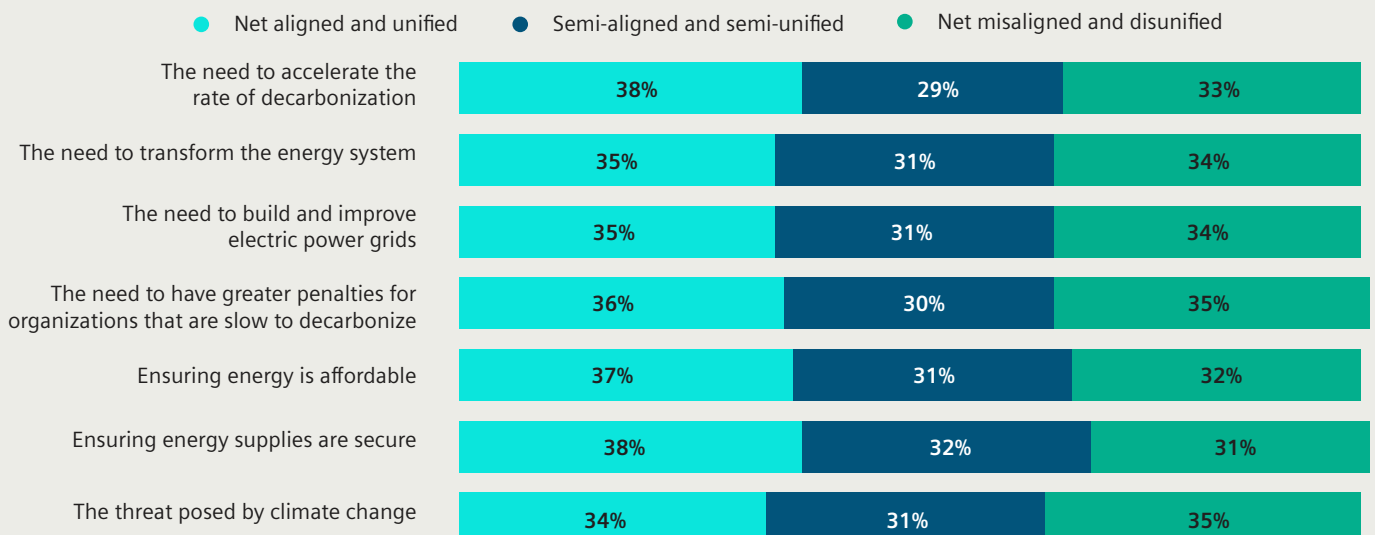
Different stakeholders and countries will also have conflicting views on the extent to which government should be directing the path to a low-carbon economy.

ARTEA Group is a French business with an innovative business model blending real estate development with renewable energy production and smart grids. When Yaël Braun-Pivet, President of the French National Assembly, visited Philippe Baudry, Chief Executive Officer of ARTEA Group, she asked him about their model: “What do you need to go faster?” Baudry replied: “We just need freedom. There’s too much regulation. Everything is too complicated, which means my engineers spend half their time on regulatory planning and administration.”

Electricity is a complex, critical system, and leaders like Baudry are not advocating for compromises on the fundamentals of regulation. However, our research suggests that regulators and lawmakers need to adapt faster, streamline processes, and eliminate delays. However, our research suggests that regulators and lawmakers need to adapt faster, streamline processes, and eliminate delays.

How well aligned are citizens, business and government on key issues in the infrastructure transition?

Note: Percentages may not sum to exactly 100% due to rounding.



TRENDS IN TRANSITION

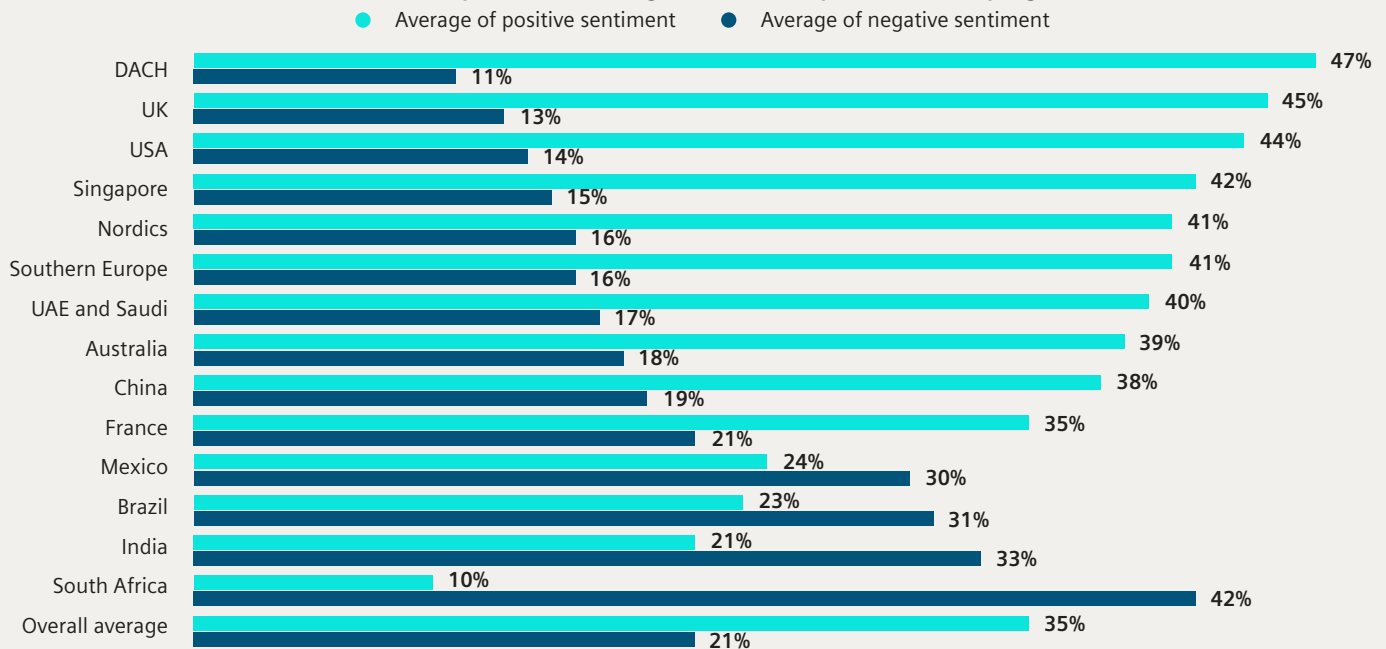
The great development divide

Net zero depends on developing countries and emerging markets. In 2021, the International Energy Agency (IEA) warned that emerging and developing economies needed to increase their investments in clean energy by more than seven times (to about \$1 trillion by 2030) to get the world back in line with Paris Agreement goals. Our research suggests that this isn't happening.

One reason for this is that developing countries and emerging markets are often facing other pressing priorities, such as poverty reduction and economic development, which can make it difficult to invest in clean energy. Another reason is that the cost of clean energy technologies is still relatively high and developing countries and emerging markets struggle to afford them.

Half the executives we surveyed say the infrastructure transition is accelerating in their region, but this falls to a third in India, Mexico, and Brazil, and just 13% in South Africa. Most executives in India, Mexico, Brazil, and South Africa say their decarbonization strategy is not consistent or effective.

More developed countries/regions are more positive about progress



We asked respondents to **select three words or phrases (from a list of 11) that best describe their country's or region's current progress in the infrastructure transition**. Five of the words were positive (accelerating, coordinated, on target, agile, effective) while six were negative (too slow, chaotic, off-course, inflexible, at risk, short-sighted).

This chart shows the average frequency of selection across the positive and negative words/phrases (overall, and by country).

Despite the challenges, there are some positive trends developing. For example, many developing countries, particularly in Asia, are shifting to electric two/three-wheeled vehicles (bikes, scooters, etc.). In China, sales of these vehicles grew by close to 25% per year in the five years to 2021⁴, by which point seven in every ten two-wheelers sold were electric⁵. Vietnam and India are following a similar trajectory, though significantly behind China’s progress. In these markets, two/three-wheeled vehicles account for about half of all road transport gasoline consumption, so electrification can significantly cut the use of oil and the release of emissions.

Shifting to electric two/three-wheeled vehicles is both simpler and cheaper than many other decarbonization goals, including, notably, the decarbonization of the electricity needed to charge them. But larger infrastructure projects in developing countries can suffer from a lack of access to finance, which leaves many projects stuck in the planning phase of development.

“Accessing climate finance is a crucial challenge for many cities – especially in the developing world,” says Cassie Sutherland of C40 Cities. “Limited international funding hinders urban climate initiatives, affecting investment in energy systems, waste management, transportation infrastructure, and water-related challenges. To accelerate renewable energy adoption, increased private investment is necessary, accompanied by the withdrawal of government subsidies for fossil fuels. However, the movement of financial resources remains overlooked. Funds often fail to reach city budgets, and cities lack agency in advocating for dedicated climate financing.”

Relying solely on government funding will be challenging during a period of economic uncertainty and fiscal constraints. Alternative funding mechanisms such as public-private partnerships (PPPs), green bonds, infrastructure investment funds, and international cooperation can help to bridge the financing gap.

⁴ <https://www.iea.org/reports/global-ev-outlook-2022/trends-in-electric-light-duty-vehicles>

⁵ <https://about.bnef.com/blog/two-wheelers-on-a-steeper-path-to-zero-emissions-by-2050/>





Sphere 2

THE CITY PERSPECTIVE

**Integrated sectors and the
decarbonization of cities**

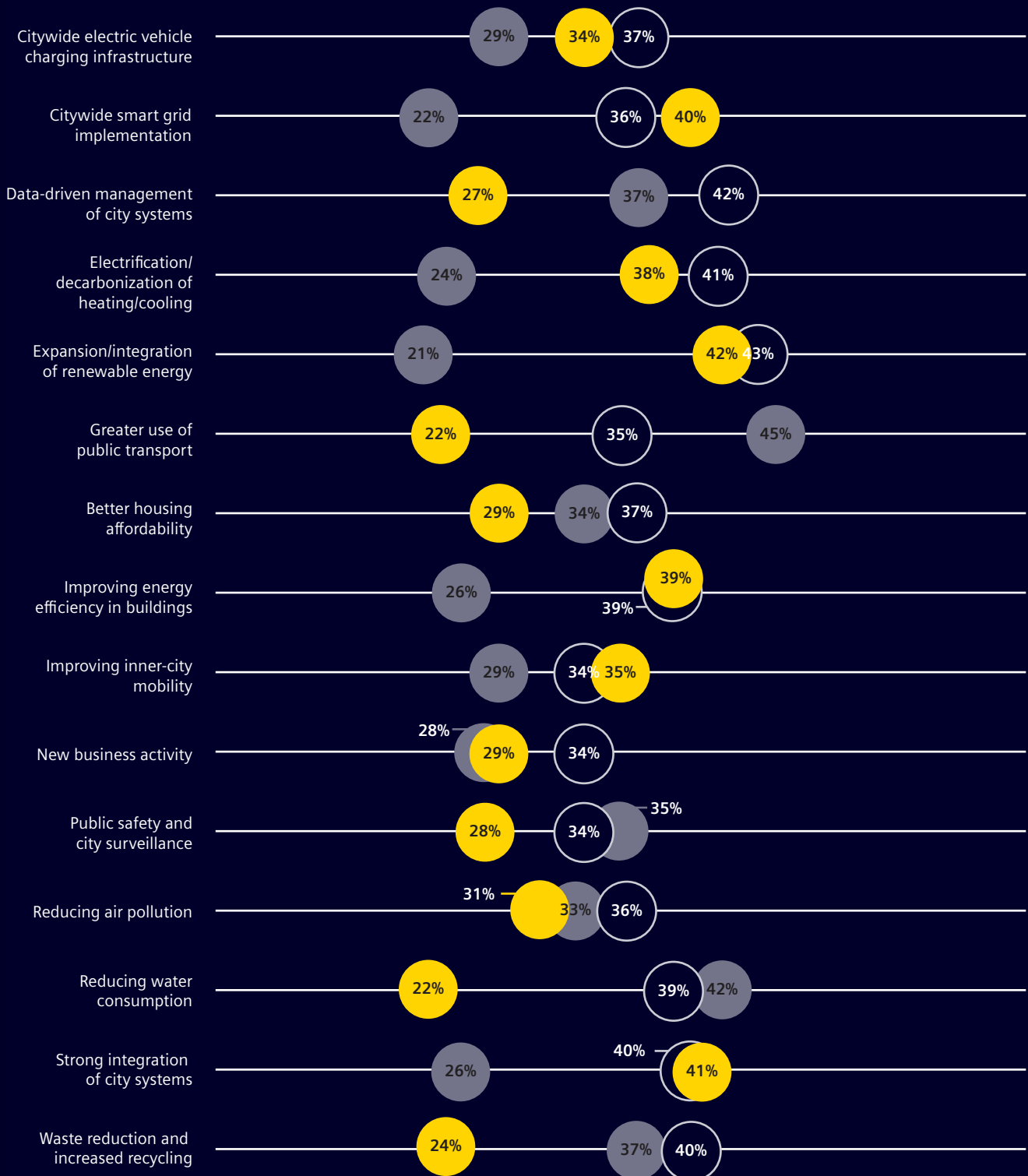


Much of the infrastructure transition needs to occur in urban areas, but rapid progress is challenging. Our research finds only 22% say that the **implementation of citywide smart grids is mature or advanced**. Only 21% say the same for the **expansion and integration of renewable energy**. Are Cities struggling to digitalize and decarbonize at the same time? The City Sphere looks at the big issues in urban infrastructure transformation and investigates how to accelerate the transition of complex clusters of infrastructure elements.



Progress and priorities on infrastructure transition goals for cities

● Advanced/mature ● Planned (but undeveloped) ○ Budget priority



- The greatest level of progress is in public transport use - **45%** report mature or advanced progress.
- Only about one quarter (**26%**) say that their cities are mature or advanced on the integration of city systems.

- Integration of systems is among the highest priorities, as is the related goal of citywide smart grids.



Why focus on **cities**?

Cities are where everything comes together: all the industries, markets, and populations, and all the systems that support them. Every year, urbanization and population growth increase the environmental footprint of cities. And while every city is different, there are common issues and infrastructure transition strategies that are only visible at city level. Cities are an opportunity to integrate different sectors and deploy truly joined-up infrastructure strategies.

Cities are also major sources of greenhouse gas emissions. If they can change and adopt sustainable practices, they will achieve significant emissions reductions. It's a concentrated impact that's motivating many mayors to lead their cities to greater climate action. Reducing emissions from urban sectors such as transportation, buildings, and energy systems makes cities an important battleground in the fight against climate change.

Crucially, cities can outpace national governments on rapid change. "Cities can possess remarkable agility and flexibility," says Cassie Sutherland, Managing Director, Climate Solutions and Networks at C40 Cities. "A significant advantage that cities have over national governments is their ability to swiftly deliver and implement solutions – often on accelerated timelines. Mayors are at the forefront of this, because they have intimate knowledge of local needs and living conditions. Even in large cities, mayors can often act more promptly than their national counterparts."

National governments play a crucial role in setting policies and creating a broader framework for action, but cities can use their greater agility, localized insights, and strong mayoral leadership to put climate solutions in place more swiftly and effectively.

How can cities accelerate the **decarbonization** of mobility?

Within cities, mobility is always a big issue. It is critical to economic growth, consumes significant resources, and issues like congestion and pollution impact our quality of life. It is also a major source of greenhouse gas emissions, rapidly electrifying in places, and on the cusp of a major transformation as automation, AI, and data-driven strategies influence many areas.

Cities are also home to the largest public transport networks and concentrations of commercial and private vehicles. Among our set of urban infrastructure transition goals, respondents feel that their cities have made the most progress on encouraging greater use of public transport, with 45% rating this as mature or advanced.

Changing urban mobility infrastructure is a big, difficult job. The most obvious challenges stem from the complexity of urban transportation systems, the need to integrate infrastructure systems within busy, built environments, and the sheer scale of funding required.

These can all be addressed with good strategy, but some issues can only be tackled with the right policy. For example, how should we accelerate the shift away from fossil fuel powered vehicles?



Should **petrol/diesel cars** be taxed off the roads?

Mobility policies need to support the decarbonization of private transport – usually by encouraging people to use electric vehicles.

“We still see a lot of non-electric cars in cities, even where there is good charging infrastructure,” says Marco Luethi, Director at Verkehrsbetriebe Zürich. “This is because the initial cost of purchasing an electric car is much higher than an equivalent petrol or diesel car. In my opinion, we need to levy stronger penalties on non-sustainable energy consumption and penalize petrol and diesel vehicles more.”

In our survey, 46% of the executives say that subsidies or taxes should be used to make electric vehicles cheaper than petrol/diesel vehicles, and only 25% disagree, but there was a large amount of regional variation. And it’s political: this is the kind of policy that can win or lose an election.

“In Switzerland, at the moment, politicians are not willing to penalize ownership of an internal combustion vehicle,” says Luethi. “But this is one of the biggest things we need to focus on if we want to get the cars we have today out of cities and achieve our net zero emissions goal.”



What comes first: more **electric vehicles**, or more **charging infrastructure**?

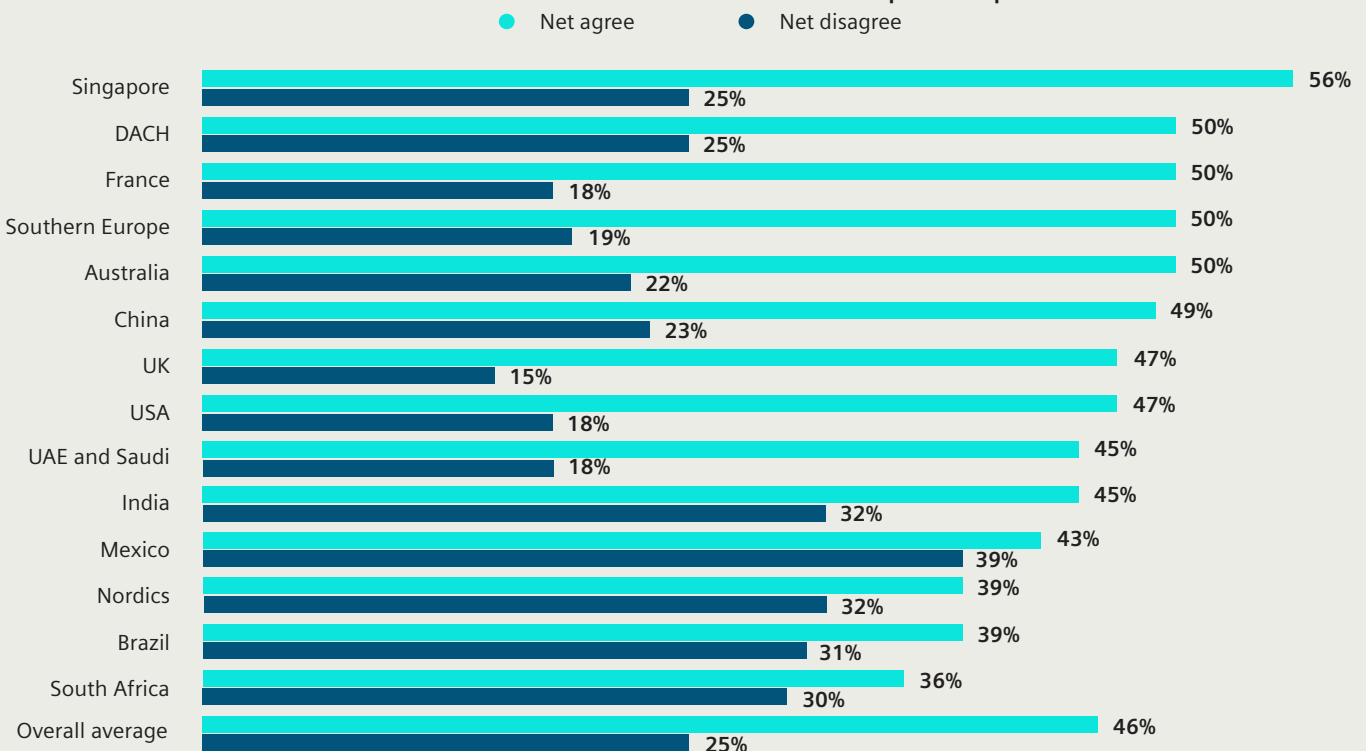
A minority of respondents (29%) can report mature or advanced progress in city-wide electric vehicle charging infrastructure. Some leaders feel that they cannot enact policies that favor EVs until there is widespread vehicle charging infrastructure. Others argue that by stimulating demand for electric vehicles they will spur greater roll-out of EV infrastructure. On this debate, the urgency of the transition is a key factor.

“Infrastructure must come first for decarbonization,” says Matteo Craglia, Transport Analyst & Modeler at the International Transport Forum (ITF). “Without charging infrastructure, electric vehicles can’t be adopted. The same is true for low-carbon fuels. This is a challenge because there’s no demand for these fuels yet, which makes infrastructure projects financially risky. But governments must help to manage these risks by providing direction to the market and

potentially subsidizing infrastructure in the short term. This will help to create demand and accelerate the decarbonization process.”

The lack of charging infrastructure is one of the biggest barriers to the widespread adoption of electric vehicles. Governments are starting to support the development of EV infrastructure with funding, tax breaks, rebates, or other financial assistance. By taking these steps, governments can help to overcome the barrier of charging infrastructure and accelerate the transition to a cleaner transportation future.

Subsidies or taxes should be used to make electric cars cheaper than petrol/diesel cars





Can **digitalization** enhance resource efficiency?

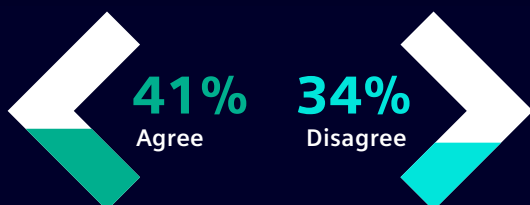
The infrastructure transition is occurring at the same time as a cascade of innovations in digital technology. These can make sustainable mobility more attractive. Mobility-as-a-service, for example, enables smooth and seamless door-to-door journeys across multiple modes of transport. These are no panacea for some of the strategic issues above, but there are near-limitless opportunities for new technologies to improve the way cities operate.

Some of these opportunities are more obvious than others. Not many of the executives in our survey recognize, for instance, that 5G mobile networks could have a positive impact on resource efficiency. "By transitioning to cloud infrastructure and leveraging 5G connectivity, we can eliminate the need for traditional cable-based systems," says Devina Pasta, Head of Technology, Digital and Strategy at Siemens Mobility, "which can lead to substantial resource savings."

There are also several ways in which 5G can support new operating models for urban infrastructure. "For example, 5G enables real-time train management, supported by artificial intelligence," says Pasta. "Which can improve safety, lower energy consumption, and minimize wear and tear on components – further enhancing resource efficiency."

A divide in transition?

The energy transition will create more jobs than it eliminates



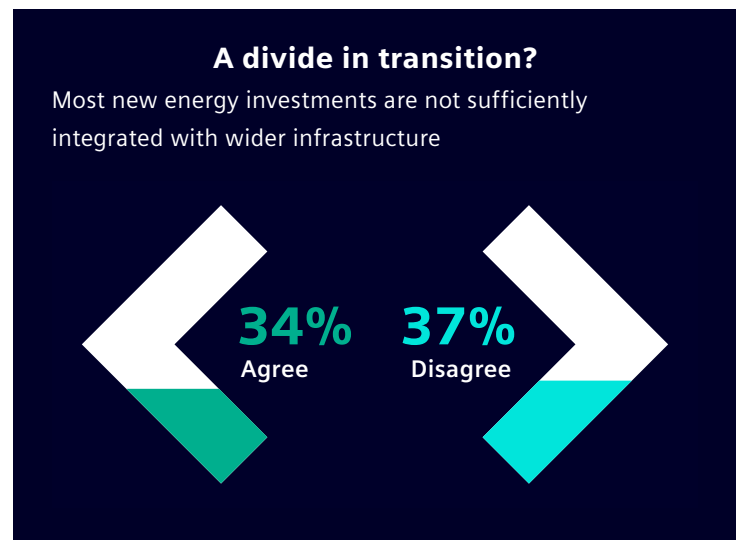
Is there enough **coordination** between sectors?

The infrastructure transition forces stakeholders to collaborate more than ever before. In many places, sectors aren't coordinating their work strategically – for example, between the transport sector and the electricity grid.

Fixing these kinds of issues likely requires a comprehensive, government-driven approach. Historically, grid investments have been incremental: they've followed demand and aimed for stability and cost minimization. Those days are over.

“Effective communication between different players is crucial,” says Matteo Craglia. “It’s increasingly clear, for instance, that electric vehicles are the most cost-effective and efficient way to decarbonize most forms of road

transport. The transport sector has a good understanding of the increasing demand for electric vehicles, but this needs to be continuously communicated to grid operators. For example, electric trucks are expected to become cost competitive in the near future, which means the grid has to prepare. Building high-power grid connections for charging these vehicles can take seven to ten years, so these conversations have to start now. Government involvement is crucial to making sure these collaborations are happening and to driving the preparations forward.”



Can we wait for **new technologies**?

The world is continually making incremental upgrades and breakthroughs in technologies that can help to implement the infrastructure transition. The sheer number of options is a challenge in itself, but the continuous change also creates uncertainty and paralysis. Is there a new technology around the corner that will be cheaper, faster, and easier? Should we hold off on a major investment until it's ready? These are challenging issues for policymakers.

"With the knowledge currently available, we can already identify the essential technological options needed for decarbonization, especially in road transport," says Craglia. "Sectors such as aviation and shipping present different technology choices – for example, methanol and ammonia – where the best option is still unclear. To reduce uncertainty, large-scale pilot projects and testing should go ahead as soon as possible."

It's important to recognize that there will always be uncertainty surrounding technologies, with different stakeholders advocating for various options. The key lies in making decisions based on the available level of certainty.

We have the tools we need. Indeed, if the infrastructure transition was only about technology and innovation, then nothing could prevent rapid progress. However, as we discuss throughout this research, other powerful forces – such as funding, politics, regulations, institutions, bureaucracy, human behavior, and supply chains – complicate the transformation.

"The key to addressing our current climate challenges does not solely lie in the development of cutting-edge technologies," says Thomas Kiessling, Chief Technology Officer at Siemens Smart Infrastructure. "While advancements in technology are valuable, they are not the missing piece that will solve the problem. Instead, what we urgently need are faster decision-making processes, improved regulatory frameworks, a heightened sense of urgency, effective execution, and an optimistic and entrepreneurial mindset to take decisive action."



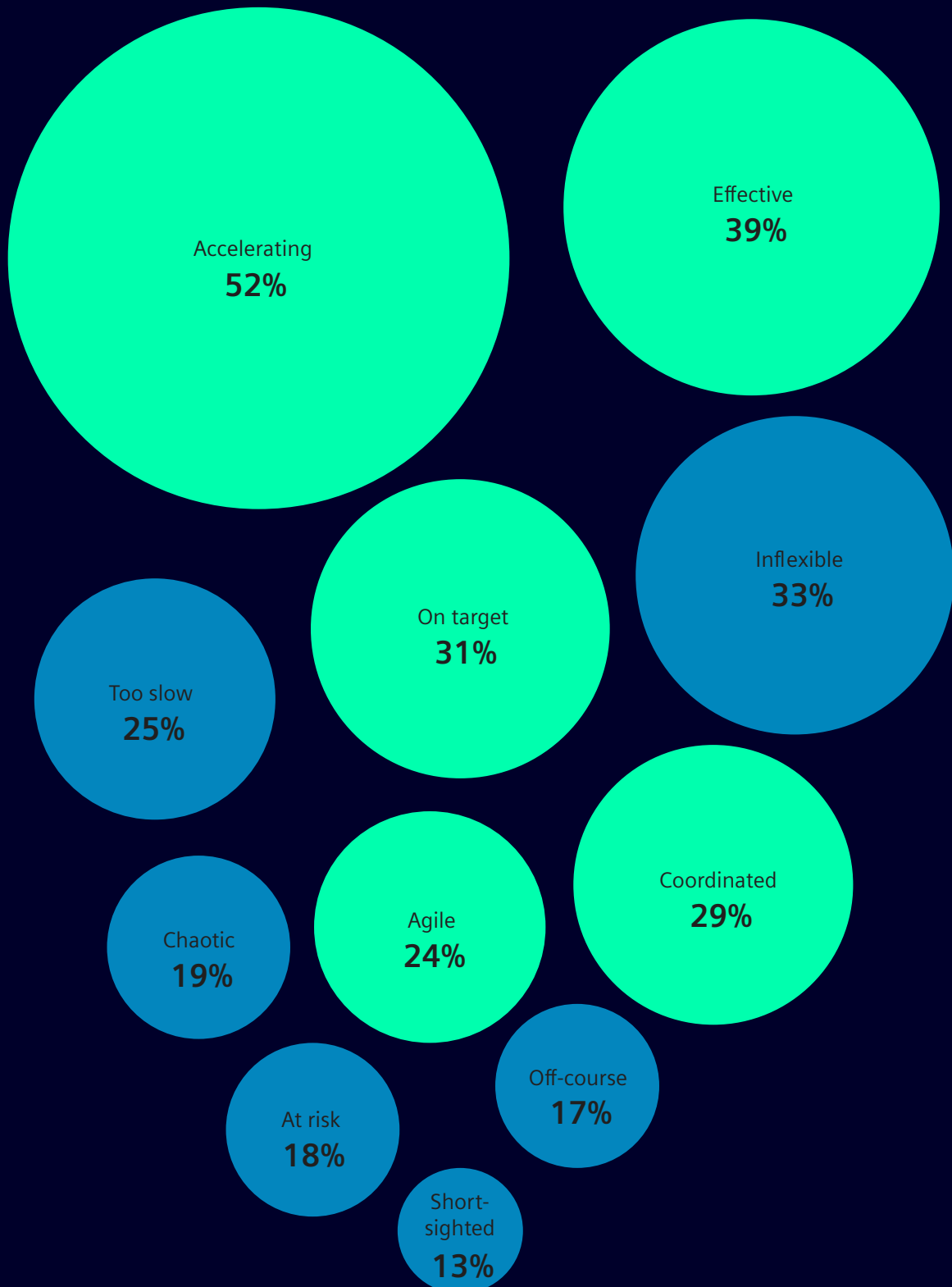
The key to addressing our current climate challenges does not solely lie in the development of cutting-edge technologies.

Thomas Kiessling

Chief Technology Officer, Siemens Smart Infrastructure

How would you describe your region's progress?

We asked respondents which of the following words/phrases best captures their region's current progress in the infrastructure transition. They could only choose three from those you see on this page. The percentages below show the proportion of respondents that included the word/phrase in their three choices.



TRENDS IN TRANSITION

Data illuminates today's cities

Data helps city officials to make more informed decisions, and it's become more available thanks to easier collection methods and improved modeling techniques. And remote sensing technologies have led to a growing number of companies willing to provide data to cities.

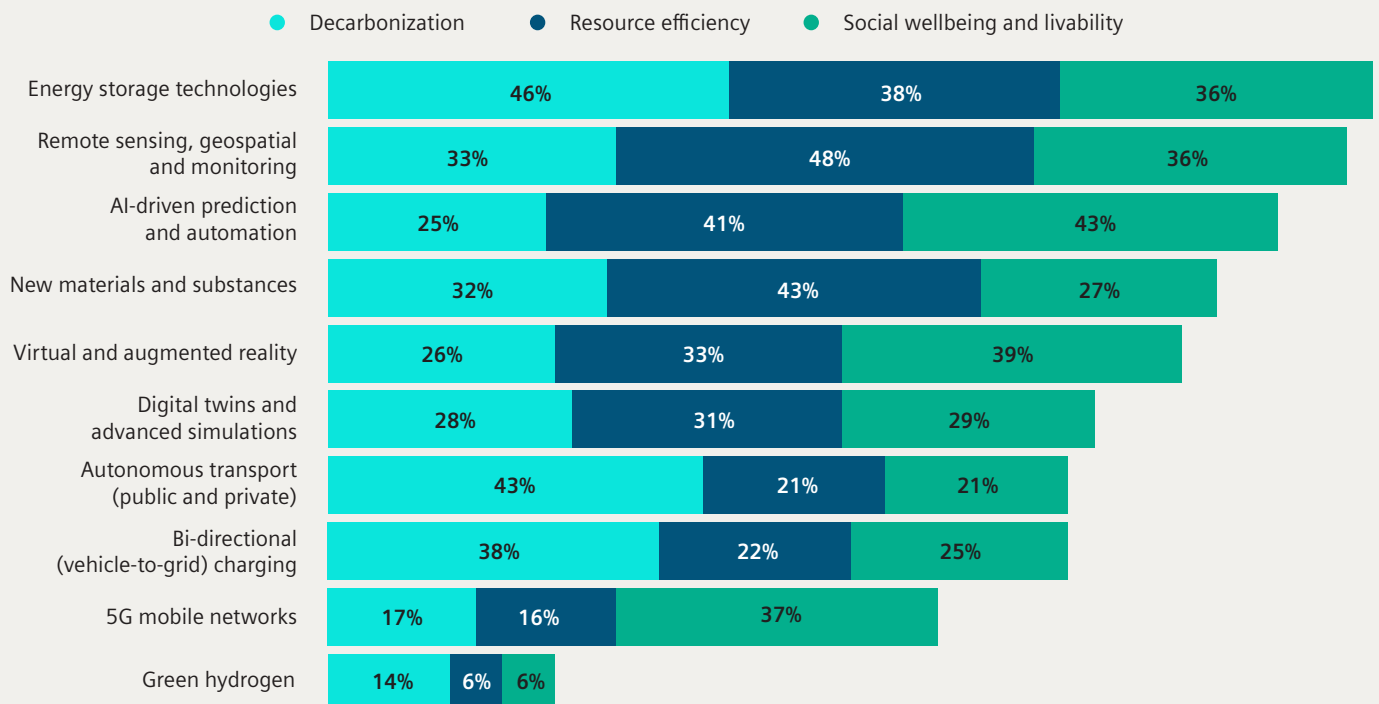
The adoption of air quality monitoring in cities has also been instrumental, because it allows for targeted interventions in areas with poor air quality. This spatial, data-driven approach yields quicker, more effective results than city-wide solutions that may not address specific hotspots."

"In the transport sector, data informs initiatives such as low- or zero-emission zones," says Cassie Sutherland of C40 Cities. "It helps identify the most polluting vehicles and enables policies to prioritize cleaner vehicles where necessary. Strategies like zero-emission freight programs and time-based curbside use rely on city-wide sensor networks for successful implementation.

Data allows authorities to target policies and measures to areas that are most in need. Overall, the expansion of data availability and its application in various domains empowers cities to make targeted interventions, address specific challenges, and improve the wellbeing of their residents.

Technologies expected to have the biggest positive impact on decarbonization, resource efficiency and social wellbeing over the next three years

Note: Respondents could choose their top three technologies for each of decarbonization, resource efficiency and social impact (to make a positive impact over the next three years). The percentages represent the proportion that selected the technology as one of their top three in each case.





Sphere 3

THE INDUSTRY PERSPECTIVE

**Business transition and the
decarbonization of industries**

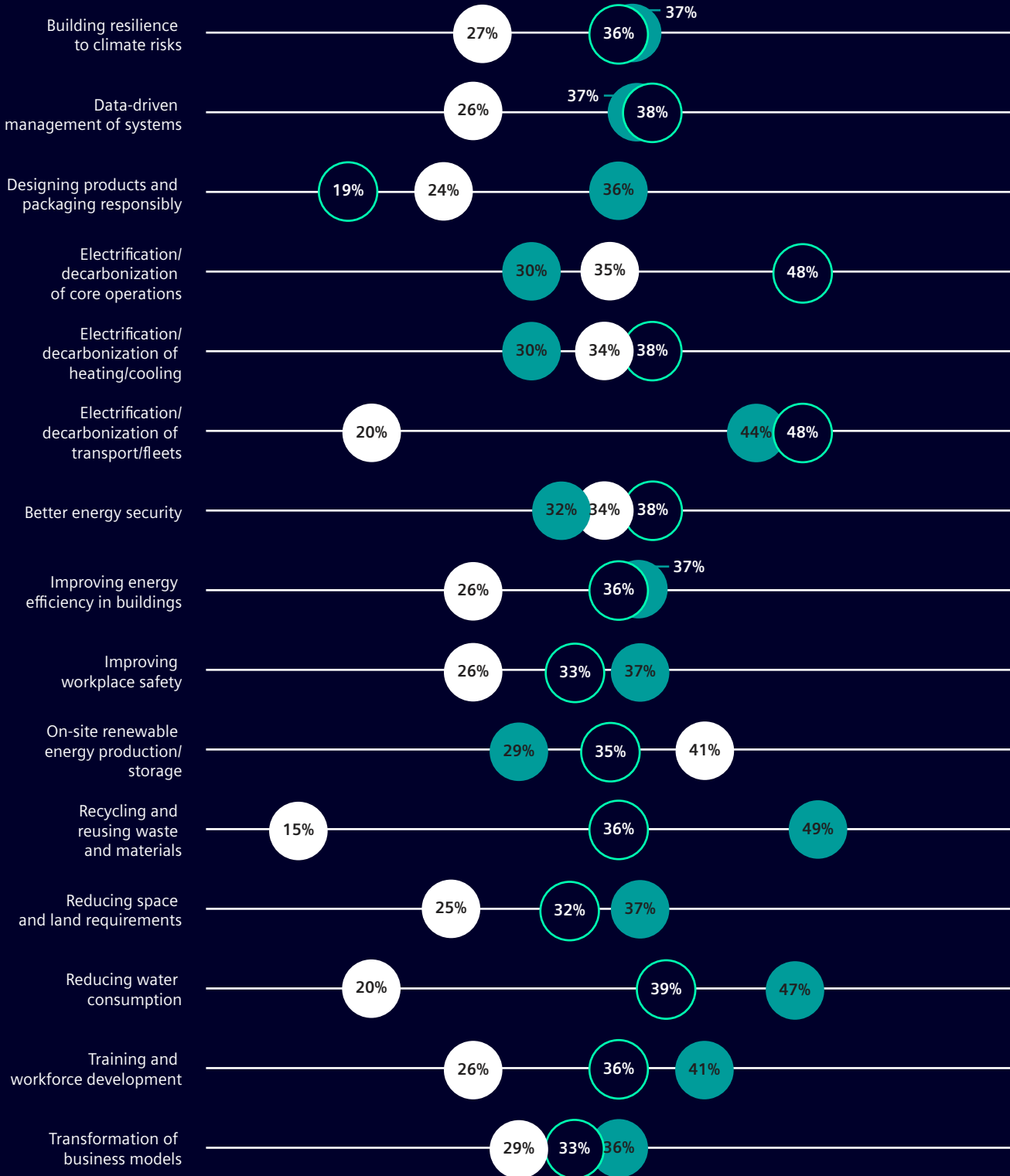


Only 40% of respondents expect their **organizations to meet their decarbonization targets this year**, and just 46% **will accelerate their decarbonization efforts in the year ahead**. A minority of organizations have made mature or advanced progress in key decarbonization areas, such as the electrification and/or decarbonization of core operations (30%) or improving energy efficiency in facilities and buildings (37%). The rate of transformation clearly needs to increase, so how can businesses overcome the barriers? The Industry Sphere zooms in to the boardroom, the campus, and the factory floor, to explore these and other issues involved in the transition of corporate and industrial infrastructure.



Progress and priorities on infrastructure transition goals for industries

● Advanced/mature ● Planned (but undeveloped) ○ Budget priority



- Progress is low in the core goal of electrifying and decarbonizing core operations – just **30%** report mature or advanced progress.
- Many more respondents have made progress on the electrification/ decarbonization of transport and fleets - **44%** mature/advanced

- Despite different levels of progress, these two goals share the joint **highest level of overall priority**.

Will companies meet their decarbonization targets?

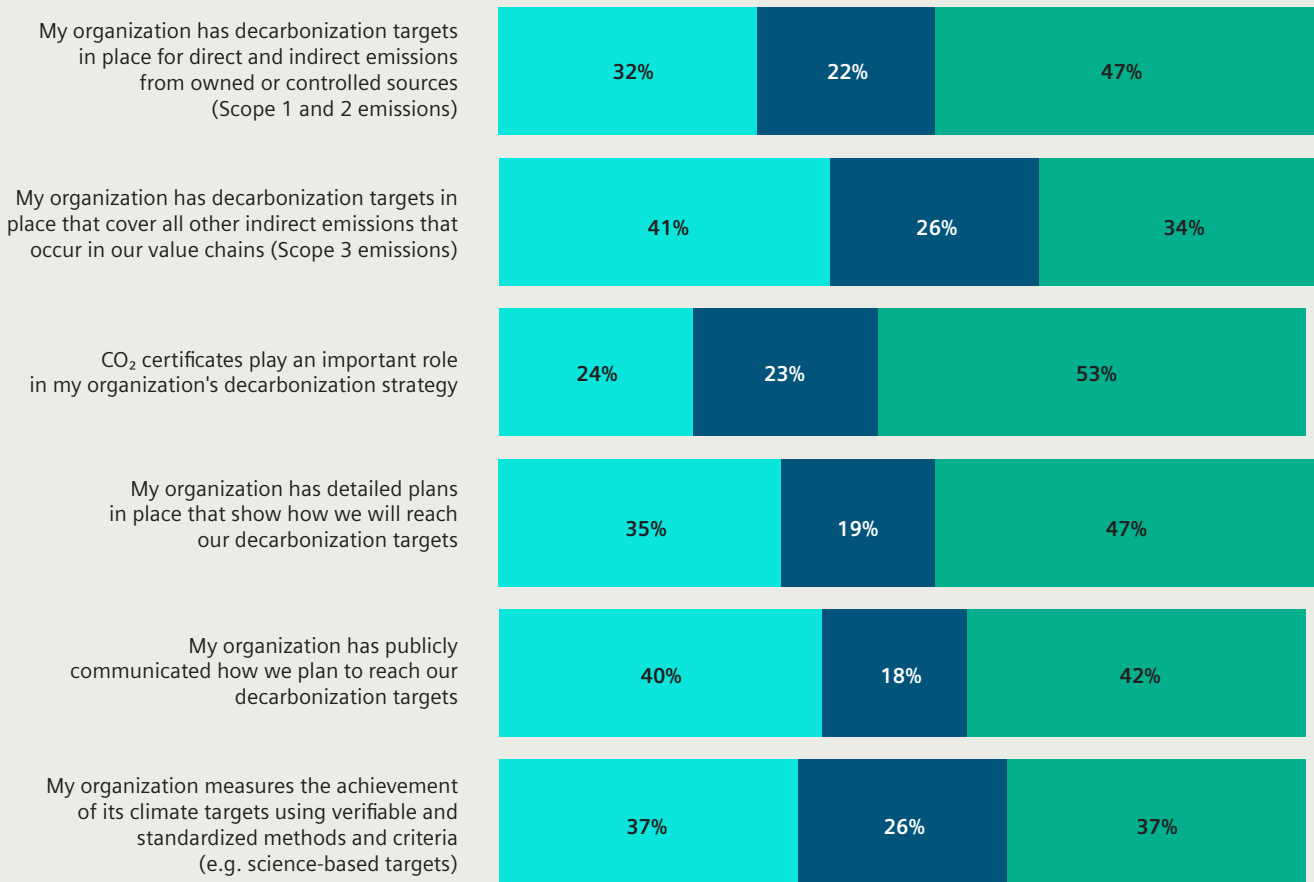
Today's business leaders are under pressure to decarbonize their business models, assets, and infrastructure to ensure a sustainable and prosperous future. It's a multifaceted problem that demands a multifaceted approach: more diverse funding sources, new risk management strategies, enhanced skills development, supply chain innovation, regulatory collaboration, and widespread adoption of digital, automated, and data-driven solutions.

But leaders are struggling with economic uncertainty, higher interest rates, inadequate supply chains, global competition, and political conflict. Only 17% of the executives we surveyed say it's "very likely" that their organization will grow revenue and/or profitability in the year ahead.

Decarbonization targets, plans, and measurement

Note: Percentages may not sum to exactly 100% due to rounding.

● Net disagree ● Neutral ● Net agree





Business prospects ebb and flow, but it's worrying to find that confidence in decarbonization targets is also low. Nearly half of the executives say they have targets for Scope 1 and 2 emissions (47%), and just 34% have targets for Scope 3⁶. Only 40% say it's either "likely" or "very likely" that their organization will meet its decarbonization targets for the year ahead; just 15% say it's "very likely." These numbers are similar for 2030 decarbonization targets, so it doesn't look like the executives are expecting any rapid improvement.

Realistic goals need to be backed by detailed plans to reach them. But only 47% of the executives say they have detailed plans in place that show how they'll reach their decarbonization targets (in whatever form or scope they take).

And targets also need to be backed up by transparent empirical methods, ideally tied to industry standards and best practice, so that regulators, shareholders, and society accept them. But only 37% of the executives say their organization measures the achievement of its climate targets using verifiable and standardized methods and criteria (e.g., science-based targets).

⁶ Scope 1 emissions are from sources owned and controlled by the organization; Scope 2 emissions are from purchased energy; Scope 3 emissions are from activities in the value chain and are not owned or directly controlled by the reporting entity.



Does rapid decarbonization require **economic growth**?

This prompts uncomfortable questions for the infrastructure transition. Will companies with weaker growth prospects be much slower to decarbonize? Are countries less likely to reach decarbonization targets when economic growth weakens?

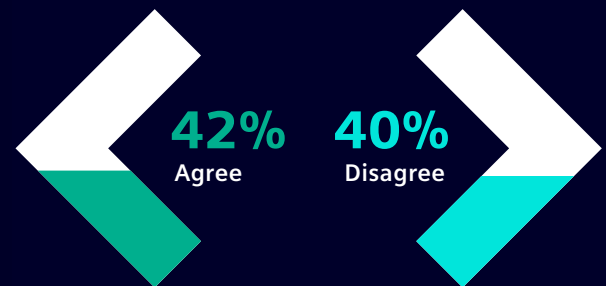
Some studies suggest there's a strong correlation between confidence in organizational growth prospects and confidence in decarbonization targets⁷, and some suggest that strong economic growth contributes positively to national targets, while weak growth does the opposite⁸.

In 2023, many countries are at risk of, or are already in, recession. So it's worrying that the executives we surveyed say economic recession is the factor that would do more than any other (from a list of 17) to slow down their industry's transition to clean energy.

Growth, of course, isn't the only factor that decides whether a company or country can reach its decarbonization targets. Political will, public support, leadership, shareholder activism, and workforce preferences are all important. Many of these factors also impact another vital ingredient: capital.

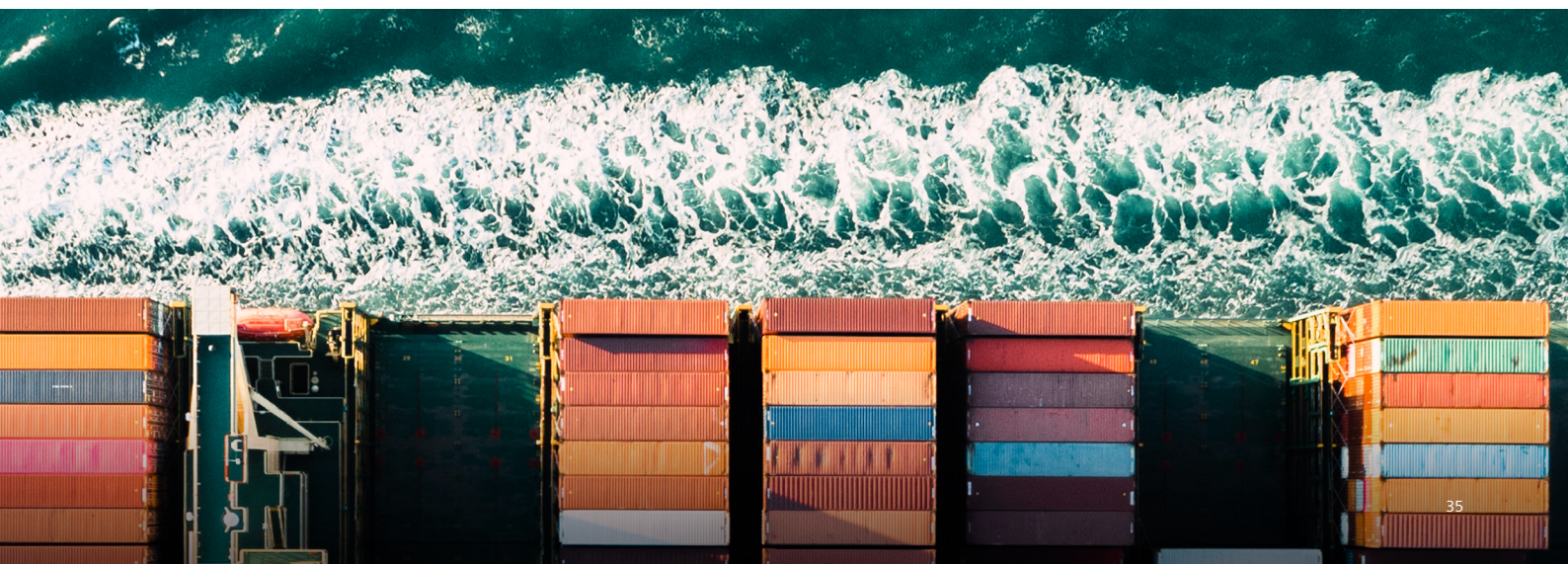
A divide in transition?

My organization has publicly communicated how it plans to reach its decarbonization targets



⁷ <https://www.weforum.org/reports/the-global-risks-report-2020/>

⁸ <https://www.nature.com/articles/s41558-023-01661-0>



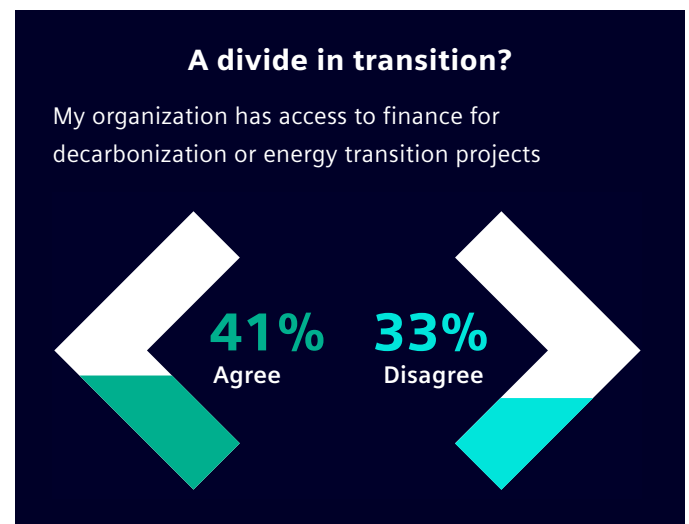
Can investors encourage progress despite the headwinds?

In our survey, a minority of respondents' organizations have made mature or advanced progress in key decarbonization areas, such as the electrification and/or decarbonization of core operations (30%) or improving energy efficiency in facilities and buildings (37%).

However, while current progress is limited, we can expect an acceleration in development toward these goals: decarbonization goals are rated as the highest priority for the year ahead, topped by the electrification and/or decarbonization of transport and fleets, and of core operations.

Accelerating these areas is often capital intensive. The support of banks and investors is vital to keeping decarbonization going through times of slower growth. Companies can also face trade-offs between financial performance and decarbonization goals, and many clearly lean in one direction or the other. For instance, in our survey, a third of respondents (33%) say their organization puts cost and revenue considerations first when choosing a decarbonization strategy. However, 44% say that their organization prioritizes finding the quickest way to decarbonize, ahead of cost or revenue implications.

Climate risks, decarbonization, and energy transition metrics are also increasingly part of debt and equity funding considerations. "Banks ask many questions about sustainability before they will lend, including requesting data on many different kinds of metrics," says Delphine Esculier, CSR Director at Elixor/Derichembourg Group. "This is still quite new, and it's important that all parts of our company are committed to tracking the right data so we can adapt to each investor's requirements."



Banks ask many questions about sustainability before they will lend, including requesting data on many different kinds of metrics.

Delphine Esculier
CSR Director, Elixor/Derichembourg Group

Are businesses **decarbonizing** their buildings?

The goal of improving the energy efficiency of buildings is among the most important aspects of the infrastructure transition. Globally, buildings contribute 39% of energy-related carbon emissions – 28% from operations (heating, cooling, and powering) and 11% from materials and construction⁹.

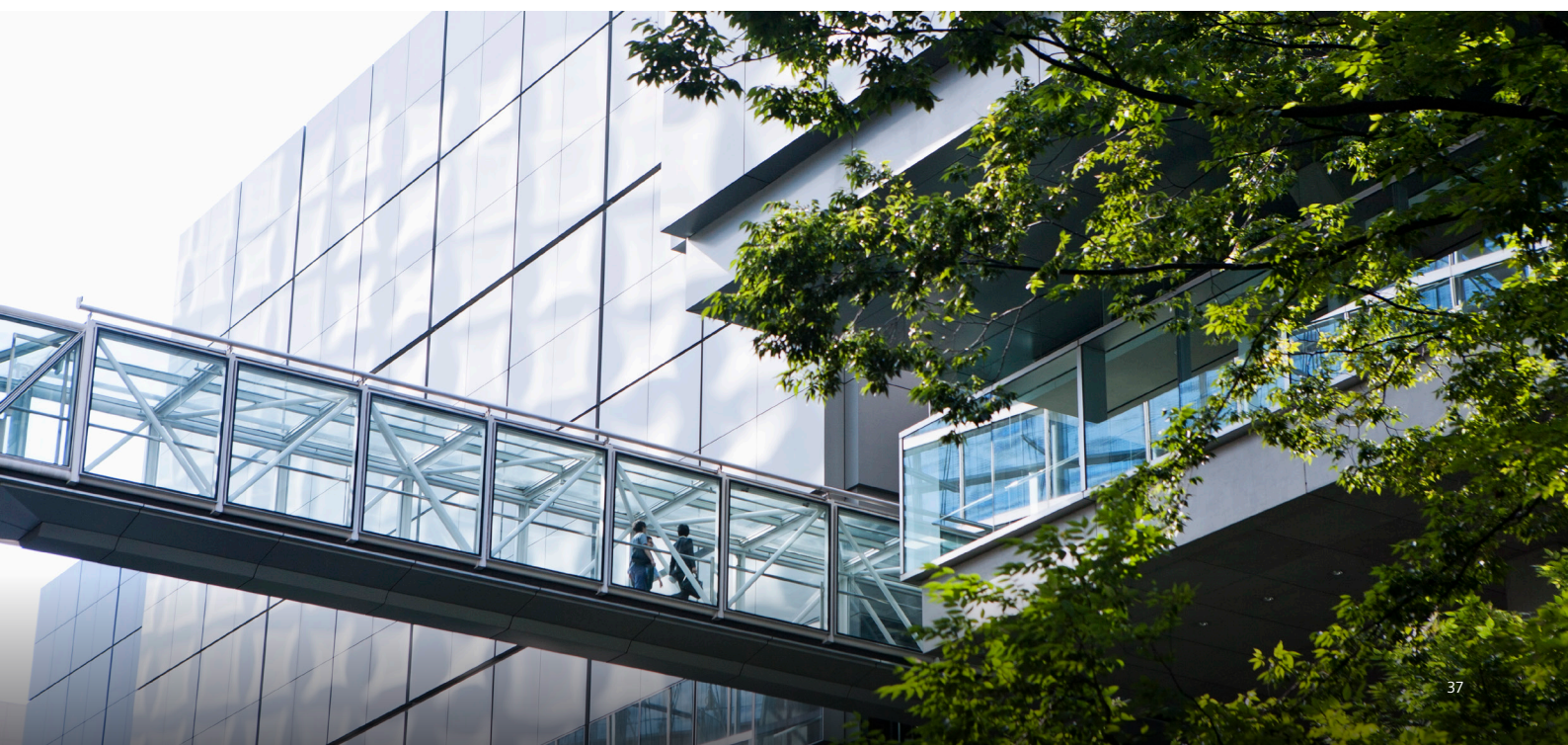
However, the impact of buildings appears underappreciated, and many organizations are not doing enough. In our survey, only 37% of respondents report mature or advanced progress on this goal. Compare this to the goal with greatest progress in this Sphere: recycling and reusing waste and materials. That goal is significantly more mature or advanced (at 49%) but is broadly comparable in terms of levels of investment, complexity, and the use of well-established technologies.

There are many organizations that have invested heavily in the energy efficiency of buildings. The UN's 2022 Global Status Report for Buildings and Construction reported that, in 2021, investments in this area increased by 16%, but the growth in floor space over the period was greater, and so energy-related emissions from buildings grew by 5%, to a new all-time high¹⁰.

Improving energy efficiency of buildings can involve both high-tech and old-tech methodologies, but these are often hidden behind walls, floors, and ceilings – there is nothing to unveil, little to photograph, no ribbon to cut. Does something as trivial as this influence investment decisions? The comparative benefits of improving energy efficiency in buildings are most impressive only once we can compare months, or even years, of pre- and post-installation performance. This could also play a role if leaders are incentivized based on short-term targets.

⁹ <https://worldgbc.org/advancing-net-zero/embodied-carbon/>

¹⁰ <https://www.unep.org/news-and-stories/press-release/co2-emissions-buildings-and-construction-hit-new-high-leaving-sector>



Is it better to **rebuild or retrofit** to improve the carbon footprint of buildings?

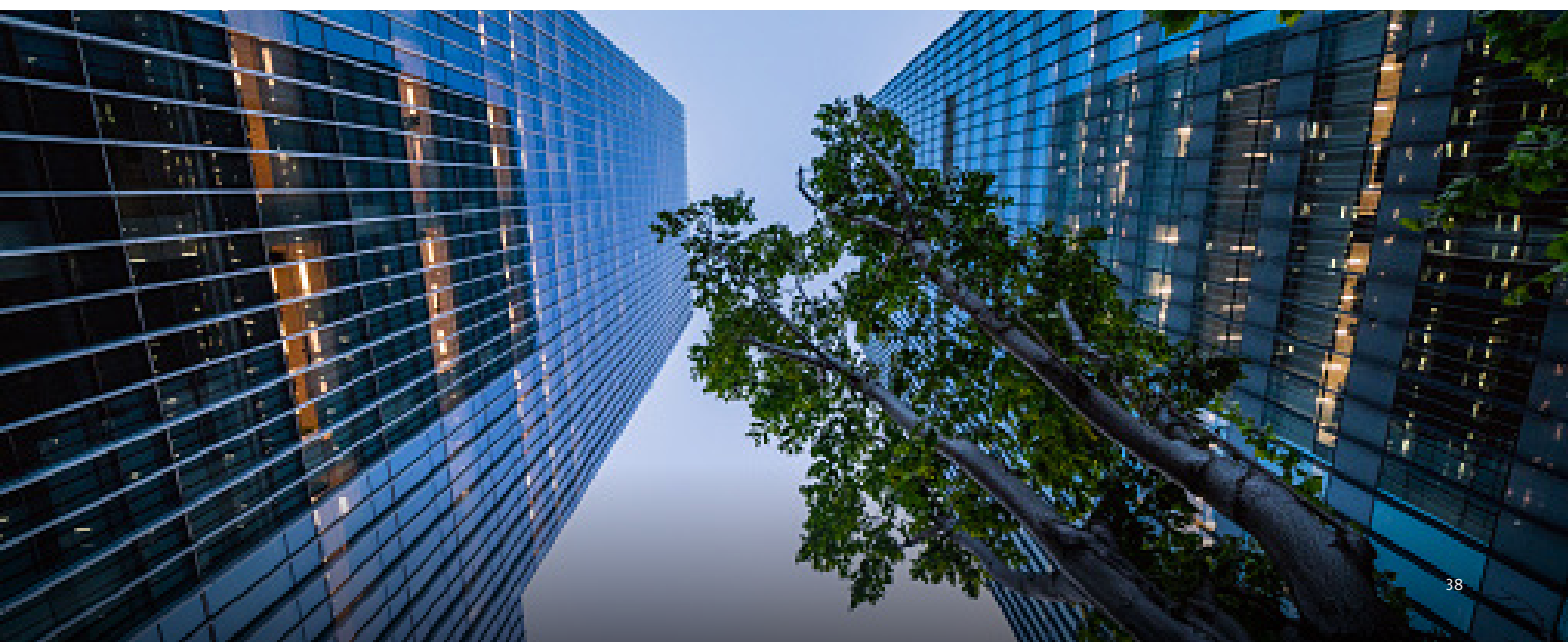
But the energy efficiency and carbon intensity of buildings should not be neglected for any reason. Businesses own or operate giant portfolios of real estate, in the form of factories, campuses, office buildings, warehouses, transport hubs, laboratories, studios, hospitals, and dozens of other buildings. It is estimated that 85%–95% of today's buildings will still be in operation by 2050¹¹. A key part of the infrastructure transition is to retrofit and renovate all our existing buildings to make them cleaner and more efficient to operate.

As we noted above, our survey shows limited progress in improving the energy efficiency of facilities and buildings, and just 30% have made mature or advanced progress in the electrification and/or decarbonization of heating and cooling.

“It is crucial to prioritize existing buildings in our efforts,” says Cassie Sutherland of C40 Cities. “Cities can leverage their authority in various ways, such as implementing building codes that promote reduced construction. This approach maximizes the utilization of existing built assets, allowing sites to be renovated and regenerated instead of being demolished and rebuilt. Not only does this approach yield substantial savings, but it also maximizes available resources.”

This is one area where consensus does seem to be gathering. “The greenest building is the one we don't have to build, the one that's already built,” says Saul Humphrey, Professor of Sustainable Construction Management at Anglia Ruskin University. “Rather than focusing on constructing new eco-friendly buildings, we should enhance the ecological footprint of our existing structures. Retrofitting and refining such spaces to meet higher benchmarks of energy efficiency and sustainability almost always saves more emissions than demolition and rebuilding.”

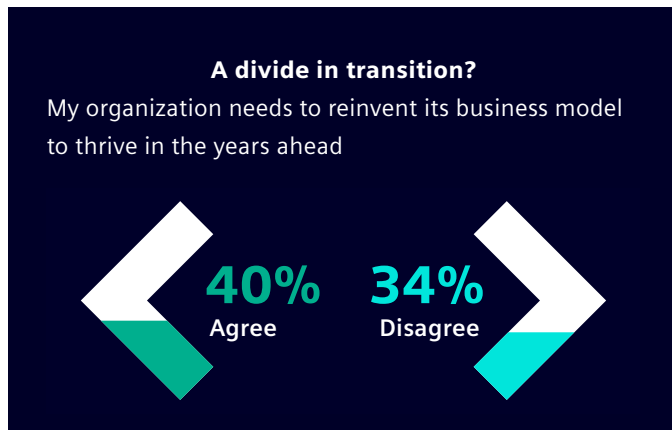
¹¹ <https://www.eea.europa.eu/publications/building-renovation-where-circular-economy>





The importance of improving the current building stock has been recognized, but this needs to translate into greater action. In some parts of the world, it is likely that the coming years could see a boom in retrofitting activities. “In the past, it was often deemed too costly to integrate advanced technology into existing buildings, despite the evident benefits. However, the landscape has shifted significantly,” says Dave Hopping, CEO of Siemens Smart Infrastructure Solutions & Services. “Today, there is a notable shift across various sectors – be it hospitals, commercial office buildings, educational facilities, or industrial sites. Customers are increasingly focused on exploring all possible avenues to avoid constructing new buildings. This changing mindset is driven by economic considerations and a desire to maximize existing resources. Retrofitting existing buildings with advanced technologies has become a more feasible and cost-effective option.”

By leveraging innovative solutions, businesses can enhance the performance and sustainability of their buildings without the need for extensive new construction, but progress needs to accelerate.



Can new business models keep the **transition** moving?

Respondents believe that their industry’s transition to clean energy would be most accelerated by investment in skills, strong economic growth, and subsidies/incentives. Conversely, they believe this transition would be most slowed by economic recession, lack of skills, and energy system uncertainty.

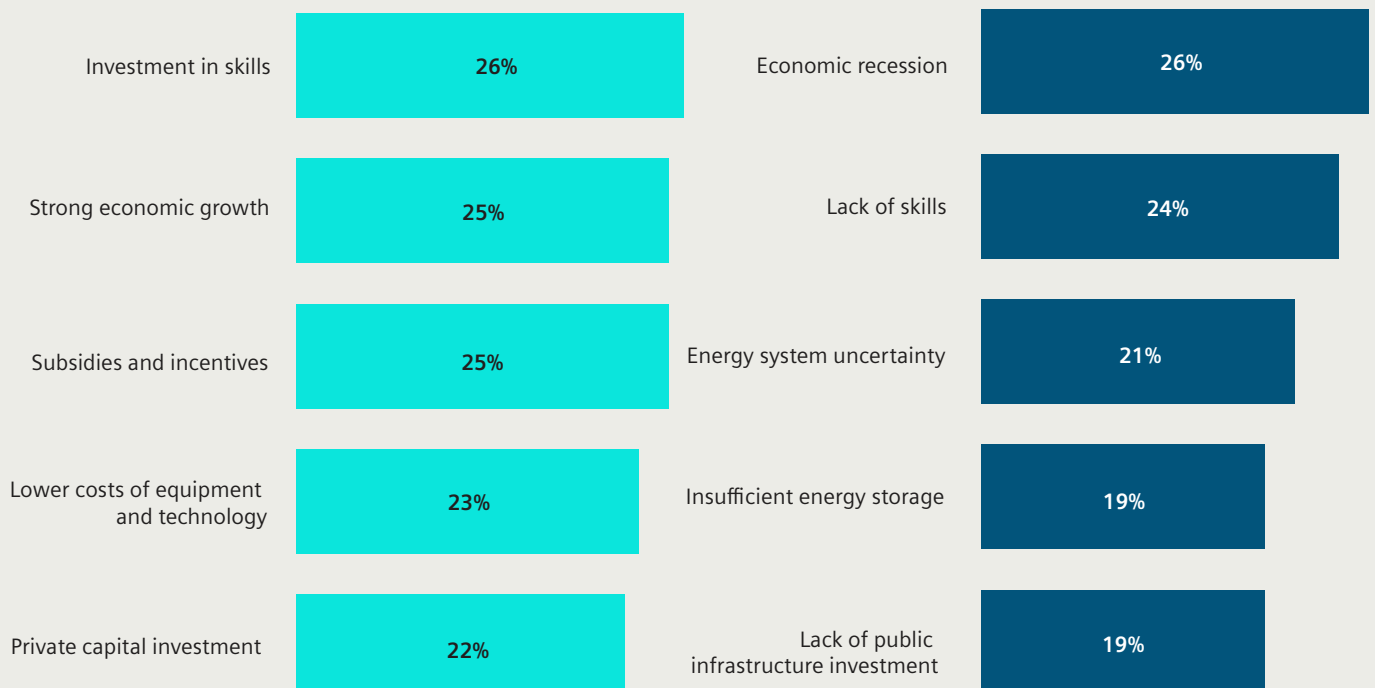
One way to sustain progress across many aspects of the transition is to treat infrastructure as a service instead of an asset. “Capital is growing more expensive, with interest rates rising around the world over the past few years,” says Hopping. “But this has led to progress in the development of new business models, where capex is substituted for opex and organizations purchase an outcome, a service, or a specific benefit – rather than assets.”

This can work for many types of infrastructure. “In our business, the main barrier is often the price,” says Corinne Grapton, CEO of Le Studio LED. “Customers put more focus on capital outlays than on related expenses over time. Part of what is needed is to communicate that our products will last longer and use less energy, but we also need new models, which is why we now operate lighting-as-a-service, which frees up capital for the customer while allowing us to optimize their energy consumption and efficiency over the long term.”

Digitalization is important here, because it’s only by gathering and analyzing data from dozens of lighting projects that Le Studio LED can prove to new customers that its approach is cost-effective and energy efficient.

Top 5 factors impacting the speed of transition to clean energy

● Top five accelerators ● Top five decelerators



TRENDS IN TRANSITION

Supply chains are holding back the transition

Just 46% of the executives we surveyed say their organization is likely to accelerate decarbonization in the next year. For many, the top limitation is securing the equipment they need to build clean energy and decarbonization assets. For example, many businesses that want to quickly replace fleets of diesel delivery vans with electric replacements are currently limited by shortages and long delivery times¹².

Equipment providers, meanwhile, are held back by capacity constraints that take time to expand, as well as shortages of semiconductors and the critical minerals needed to manufacture clean-energy technologies such as solar panels, transmission lines, electric vehicle batteries, and wind turbines. These supply chain disruptions can cause “delayed and more expensive energy transitions,” and disruptions can lead to unwelcome trade-offs, where organizations have to accept strategies that aren’t ideal¹³.

Supply chain issues are likely to persist in one form or another during the next decade, as demand for clean energy assets and equipment soars. This could lead to periodic price spikes, stock shortages and delivery delays. According to the IEA, the cost of the critical minerals required for the energy transition could reach \$1 trillion by 2050, and shortages of critical minerals could delay the energy transition by up to 15 years¹⁴.

¹² <https://www.reuters.com/business/autos-transportation/lack-electric-vans-opens-door-chinese-other-ev-makers-2023-04-13/>

¹³ https://iea.blob.core.windows.net/assets/6fe16228_521a-43d9-8da6-bbf08cc9f2b9/SecuringCleanEnergyTechnologySupplyChains.pdf

¹⁴ <https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>



How do we act quickly in conditions of uncertainty?

Executives believe energy system uncertainty is a powerful factor (the third highest) in slowing progress towards clean energy. In every Sphere we have explored, uncertainty has been an issue, from the consistency of regulatory frameworks to the direction of unfolding models, markets, and technologies that will underpin the infrastructure of the future. How do decision-makers overcome the paralysis that uncertainty can bring?

Perhaps by accepting that uncertainty is here to stay, and that today's leaders have a responsibility to make bold, sometimes historic, decisions without as much information or certainty as they may have had in the past. The infrastructure transition is a shift to a world that is gradually taking shape, not from some blueprint, but through a cycle of exploring possibilities, building strategically, and adapting as we go.

There are many difficult, important, and unanswered questions about what to do next, how best to do it, and what to expect. As a result, we should also accept that in hindsight we will see sub-optimal decisions and mistakes. No one organization has all the answers (or even all the questions). We need to continuously raise, discuss, and collaborate over these big questions. But once we have made the best decisions we can – once we have chosen the best methods, models, and technology available – the most important priority is to act quickly and keep the infrastructure transition moving forward at full throttle.



About the research

The Siemens Infrastructure Transition Monitor 2023 brings together two new sources of primary research: (1) a survey of 1,400 senior executives and (2) a series of in-depth interviews with leaders and experts.

The survey was completed in mid-2023 by senior executives from around the world. Each respondent was required to be involved in infrastructure in one of four capacities (shown below under 'Infrastructure involvement').

Survey sample breakdown

Percentages reflect the proportion of respondents in each category from the total sample of 1,400.

Countries and regions

Australia	7%
Brazil	7%
China	7%
DACH (Germany, Austria, Switzerland)	7%
France	7%
India	7%
Mexico	7%
Nordics (Denmark, Finland, Norway, Sweden)	7%
Singapore	7%
South Africa	7%
Southern Europe (Italy, Spain, Portugal)	7%
UAE and Saudi Arabia	7%
UK	7%
USA	7%

Seniority

C-suite executive (or equivalent)	14%
I report directly to a C-suite executive (or equivalent)	36%
My boss/manager reports directly to a C-suite executive (or equivalent)	50%

Public/private sector breakdown

Private sector business	56%
Public sector administration/government	7%
Public sector services or infrastructure	21%
Hybrid public-private services or infrastructure	16%

Industry

Energy	19%
Transport	16%
Technology	15%
Health	15%
Industrials	15%
Consumers	12%
Finance	8%

Infrastructure involvement

Operator or occupant of infrastructure	48%
Designer or builder of infrastructure	39%
Owner of (or investor in) infrastructure	21%
Service provider for infrastructure	15%

Organization size

50–249 employees	21%
250–499 employees	21%
500–999 employees	25%
1,000–4,999 employees	19%
5,000+ employees	14%

Note: Percentages may not sum to exactly 100% due to rounding.

Who we spoke to

We would like to thank the following leaders and experts for participating in our in-depth interview program and sharing so many interesting and valuable insights.

Philippe Baudry

Chief Executive Officer, ARTEA Group

Matteo Craglia

Transport Analyst & Modeler, International Transport Forum (ITF)

Sabine Erlinghagen

CEO Grid Software, Siemens Smart Infrastructure

Delphine Esculier

CSR Director, Elior/Derichembourg Group

Oliver Franz

Vice President of European Associations at E.ON.

Corinne Grapton

CEO, Le Studio LED

Dave Hopping

CEO Solutions & Services, Siemens Smart Infrastructure

Saul Humphrey

Professor of Sustainable Construction Management, Anglia Ruskin University

Thomas Kiessling

Chief Technology Officer, Siemens Smart Infrastructure

Marco Luethi

Director, Verkehrsbetriebe Zürich (VBZ)

Devina Pasta

Head of Technology, Digital and Strategy, Siemens Mobility

Cassie Sutherland

Managing Director, Climate Solutions and Networks, C40 Cities

Glossary

- In this research, 'infrastructure' refers to any of the systems (e.g., electrical power systems), services (e.g., healthcare), buildings (e.g., a factory or office towers), and structures (e.g., railways) that are needed for industries, cities, and countries to function effectively.
- The term 'resource efficiency' is about minimizing resource consumption and waste through eco-efficient technologies and operations. Resource efficiency is related to, but different from, energy efficiency. It refers especially to dematerialization (reducing material consumption while delivering the same product or service) and circularity (creating closed loop systems for materials via design, recycling, reuse, repair, remanufacturing, repurposing, and refurbishment).

**Published by**

Siemens Switzerland Ltd.

Smart Infrastructure**Global Headquarters**

Theilerstrasse 1a

6300 Zug, Switzerland

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For the U.S. published by

Siemens Industry Inc.

800 North Point Parkway

Suite 450

Alpharetta, GA 30005

United States

Status: September 2023

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