SIEMENS
Ingenuity for life

Next-Gen Industrial AI

The expansion and evolution of AI within industrial organizations until 2022.

siemens.com/innovation

Contents

Introduction

The past decade has revealed the potential artificial intelligence (AI) has in industrial applications. The next challenge will be about turning that potential into business value at scale. This will involve creating novel processes and overcoming new and interesting challenges, many of which are more human than technical.

Organizations have several strategic reasons to investigate and adopt AI. These include the promise of greater efficiency, improved quality and better safety. Some are also under increasing pressure from stakeholders to expand AI capabilities to meet transformation objectives and keep pace with rivals.

So, as we enter the 2020s, many leaders in the industrial world are eager to identify the top applications for AI in their organizations, and more pressingly, to determine how these can be implemented effectively to deliver tangible outcomes.

At the same time, like all emerging technologies, AI is developing at pace. The nature of potential AI solutions could evolve quite dramatically over the months and years ahead. So, organizations need to gain a clear picture, not only of what to do today but also of what trajectory AI will take them on tomorrow.

To explore these issues, Siemens partnered with Longitude to survey more than 500 senior executives – who are responsible for, knowledgeable about, or involved with implementing their organization's use of AI – at industrial organizations around the globe.

This report summarizes our findings and offers insights which we hope will be valuable for all those considering, planning, and implementing the next generation of industrial AI.

AI in a post-covid world

When this research was commissioned, there was a lot of hype around the potential of consumer AI, and fewer insights available on industrial AI. While we at Siemens, with over 30 years' experience in industrial AI, are no strangers to this field, we wanted to learn more about the experience of other organizations. This research sought to uncover the benefits and barriers of industrial AI applications, and to highlight its potential, especially when combined with other technologies like IoT and digital twin. Suddenly the world is a different place. However, as organizations seek to recover, rebuild and adapt in a post-covid environment, the potential of industrial AI is more relevant than ever.

What is AI?

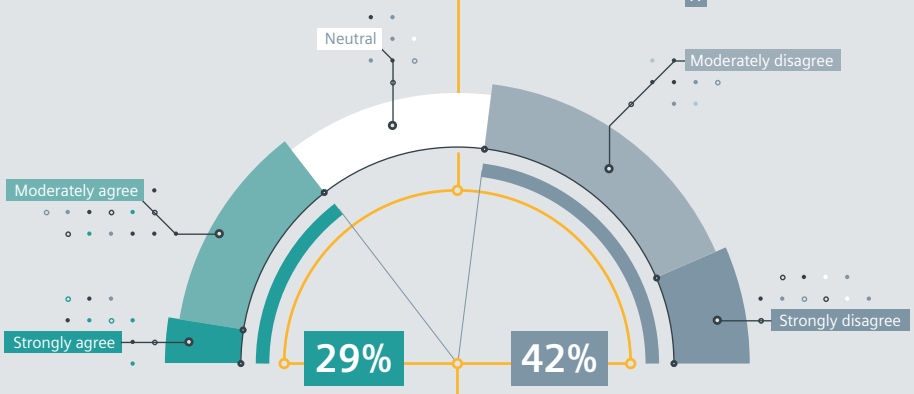
In this report, and the research that supports it, 'artificial intelligence' or 'AI' refers to a broad spectrum of methods or technologies that perform tasks which would normally require functions of human intelligence such as learning, judging, and problem-solving. This is more in keeping with the contemporary business understanding of AI, rather than any technical or academic conventions.

The past decade has revealed the potential artificial intelligence (AI) has in industrial applications. The next challenge will be about turning that potential into business value at scale.

TOP INDUSTRIAL AI ORGANISATIONS

What separates them from the rest?

"My organization is an industry leader in AI"



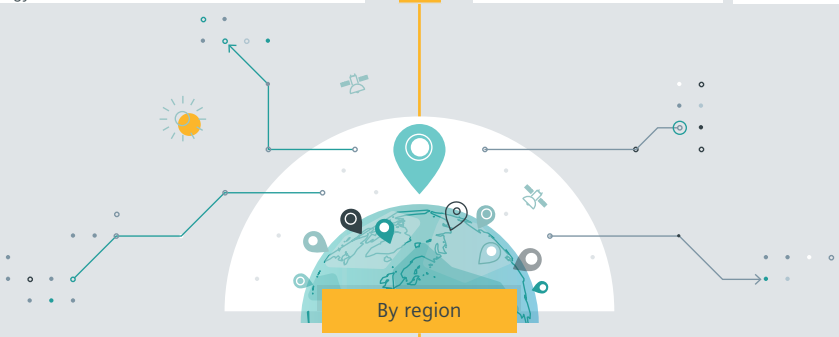
29% are **AI leaders.**
This group could include organizations with strong in-house AI expertise, successful research or pilot programs or significant investments in AI-driven applications, systems or processes.

42% are **AI delayers.**
This could include slower-to-change, poorly informed and ill-equipped organizations; but also those open to AI but yet to invest due to specific barriers or other priorities.

By industry

	AI leaders	AI delayers
Transportation	32%	43%
Urban Infrastructure	34%	32%
Industrial & Manufacturing	31%	50%
Energy	34%	43%

Half of respondents from industrial and manufacturing organizations are delayers...

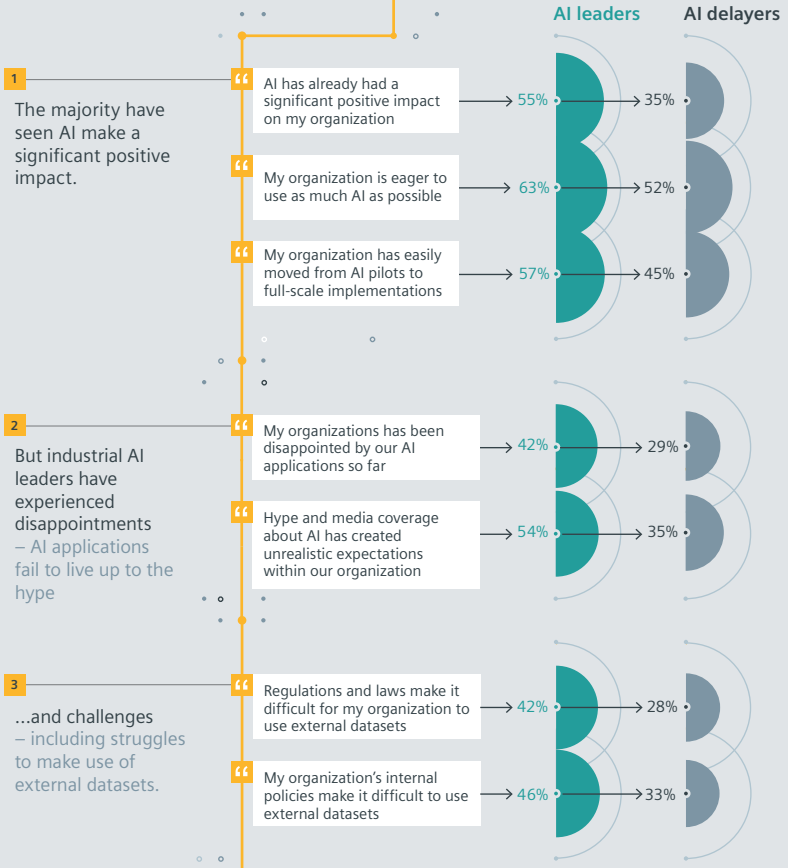


By region

	AI leaders	AI delayers
Latin America	28%	33%
North America	27%	57%
Middle East & Africa	34%	46%
Europe	26%	49%
Asia-Pacific	47%	24%

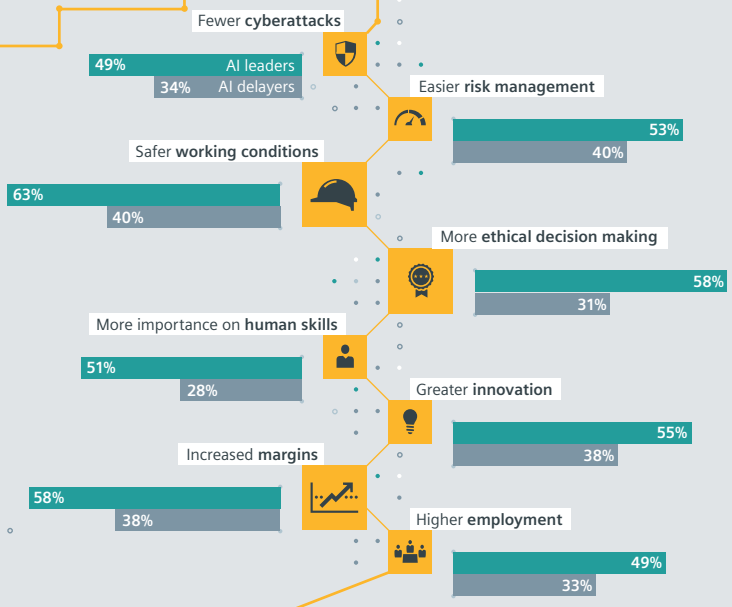
Asia-Pacific has a high proportion of AI leaders compared to the other regions...

Leading organizations have moved more easily from pilots to full-scale implementations



But nevertheless, AI leaders are much more positive about the future of industrial AI than delayers.

"As AI drives more sophisticated automation in my industry there will be:"



1 Leaders in industrial AI have a distinct outlook for the present benefits and future potential of the technology.

2 They also understand the limitations and challenges, but nonetheless believe AI will have a positive impact.

3 AI delayers accelerating their AI strategy can expect a similar outlook to develop in their organizations as their journey into AI unfolds.

1. Making use of artificial understanding

Breakthroughs in the ability of AI to overcome data integration complexities and make use of meaningful contextual data - including data describing the relationships between information - will lead to more powerful use cases.

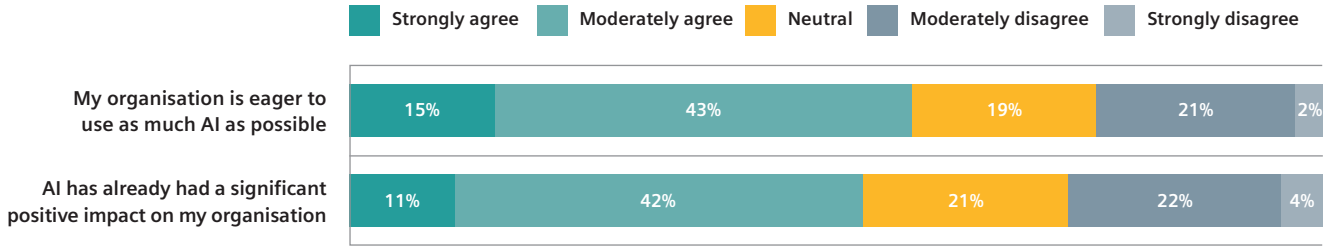
At present, AI techniques (especially machine learning) are largely used to solve discrete problems that require patterns to be identified in large volumes of a single type of data or input (e.g. data from a specific machine, or a specific video feed of a factory process).

While their usefulness is without question, these applications are made for a highly specific problem and therefore are not easily transferable for use in other areas. Indeed, many respondents to our survey (46%) say that these narrow and inflexible applications are the only kinds current AI can offer their organization.

These methods are being used in areas such as the intelligent automation of machinery and equipment – the leading area for AI applications among industrial organizations. This is closely followed by several others: safety monitoring, cybersecurity, quality control, and the optimization of processes, machines, software, or tools.

These areas can already benefit from relatively straightforward AI solutions that add classification, estimation, or clustering capabilities to speed up data processing or support new operational processes.

AI has gained significant momentum in the industrial world



The foundation of next-gen industrial AI

The next generation of industrial AI will be more impressive, both in replicating, and going beyond, many human capabilities. New applications are being driven by several forces, including supporting or enabling factors, such as capital investment, cloud data availability, and the falling cost of powerful computing resources.

In addition, there have been significant advancements in AI techniques over the past ten years, and these will play a major role in shaping the applications to come and overcoming the limitations we see today. According to Gerhard Kress, Vice President for Data Services at Siemens Mobility, until recently, AI systems trained through supervised learning required huge amounts of well-structured and perfectly labelled data sets. “This is a cumbersome approach,” he says. “In an industrial setting, applications require deep domain know-how, and there is never enough labelled data. Today, with some deep learning approaches, you don’t need as much pre-labelling because the networks essentially teach themselves.”

These ‘unsupervised learning’ approaches – where AI models discover patterns in the data independently or semi-independently (including, most prominently, generative adversarial networks) – are widely used for image recognition and are now being applied in other fields such as quality control in manufacturing, medical imaging, and autonomous driving. Reducing the degree to which we need to spoon-feed vast, perfect datasets means “these methods are now an extremely fast way for industrial organizations to make use of AI,” says Kress.

Over the next few years, we will see many more sophisticated forms of AI applications emerging. But it is also worth noting that there is still much to be done with narrow and inflexible AI, and this will continue in parallel. “Wherever we start to apply AI and machine learning in our machines, automation systems and industrial software solutions we open up the door to a next level of productivity, says Gerhard Fohringer, Head of Digitalization at Siemens. “AI will not only increase quality and availability of our productions but will enable a completely new user experience with lots of autonomous functions.”

New advances driven by new data

At the same time, many of the biggest advances expected in industrial AI are related to changes in the way data is

managed, generated, represented, and shared. For example:

- **Contextual data and simulations:** We will see AI applied to data sets created and organized in new ways to enhance insights and understanding. Examples include knowledge graphs, which capture the meaning of – and relationships between – items in diverse data sets, and digital twins, which provide detailed digital representations and simulations of real systems, assets, or processes.
- **Embedded AI and big picture insights:** Internet of Things (IoT) and Edge technologies are giving rise to diverse machine-generated data sets which can support new levels of situational awareness and real-time insights in the cloud or directly in the field.
- **Data from beyond the walls:** Improved protocols and technologies for sharing data (e.g. standardized semantic description of data sets and points) could lead to greater exchange of data between organizations, and this could help to develop AI models that simultaneously draw from the data of suppliers, partners, regulators, customers, and perhaps even competitors.

What is possible in the next few years if we use new deep learning techniques in combination with these expansions and advances in data types and availability?

It is possible that this may lead us to more generally useful and flexible AI: systems that can grasp concepts from their experiences and apply these to new situations.

For example, a system that learns to find mistakes in paintwork can transfer some 'understanding' (i.e. of visual anomalies) and apply this to find errors in other domains. This closely resembles how humans acquire knowledge in one context and apply it in another.

Benefits set to overpower barriers

In short, we are shifting from an era of narrow, inflexible AI that is slow and difficult to train, to an era of broader, more adaptable AI that is quicker and easier to train.

In keeping with this outlook, respondents to our survey appear to be factoring in an increase in the scope and scale of AI in their organizations, with considerably greater benefits expected over the next three years.

For example, 28% of respondents say automated responses to emergencies (including accidents or market shocks) are a major or moderate benefit of AI in their organization today. But 70% expect this level of benefit by 2022 – a proportional increase (vs. the current benefit) of more than 150%.

Many other benefits of AI are expected to increase rapidly over the next three years, particularly the use of AI for identifying risks or issuing warnings, and for predictive asset maintenance.

Conversely, the findings show that many of the most challenging barriers to progress with AI will decline sharply over the next three years. Data integration and quality issues will fall the most, from 73% saying this is a major or moderate barrier today, to 31% by 2022.

Dissolving data integration

It is significant that data integration issues are set to decline so sharply. "Over the past ten to 15 years there has been a trend of pulling all data together in one data warehouse and building a dashboard on top to get an overview of everything," says Kress. "This can take years to achieve as you need to normalize the data while you assemble it. It has never really worked because it takes too long, costs too much, and does not cope well with change."

Benefits of industrial AI	Current net benefits	Net benefits 2022	Proportional Increase (in 3 years)
Automate responses to emergencies, accidents or market shocks	28%	70%	154%
Identify risks / issue warnings	30%	74%	151%
Predict asset maintenance needs	28%	68%	144%
Automate processes with unstructured inputs (e.g. text, natural language)	28%	67%	138%
Automate and/or improve quality control	32%	76%	138%
Design new products and services	30%	69%	134%
Provide market or system forecasts (e.g. commodity prices, transport networks)	31%	71%	129%
Optimize systems, machines and processes automatically	32%	74%	128%
Improve existing products and services	33%	73%	122%

Barriers to progress	Net Barrier 2019	Net Barrier 2022	Proportional Decrease (in 3 years)
Data integration and quality issues	73%	31%	(57%)
Resistance to change / conservatism	76%	33%	(57%)
Lack of strategic approach	71%	33%	(54%)
Lack of leadership support	67%	31%	(53%)
Lack of technical / data skills	73%	35%	(52%)
Difficulty demonstrating return on investment	73%	36%	(51%)
Organizational silos	66%	33%	(49%)
Lack of funding	72%	37%	(49%)
Liability risks	72%	38%	(46%)
Safety risks	75%	41%	(46%)
Cybersecurity risks	76%	46%	(40%)

Increasingly we will see approaches that leave the disparate data where it is, with no attempt to standardize the data or move it into a new database. Instead, a new "glue layer" is added that links various databases together, interprets them and makes them accessible as a single source. Apart from the effort saved in bypassing traditional integration, data owners do not need to relinquish control of their databases or be forced to change their data management model – overcoming two of the major barriers that currently keep databases siloed. Introducing a glue layer requires much more computing power, but this is becoming cheaper and more accessible than ever.

Unifying knowledge graphs and AI

Knowledge graphs are one kind of "glue layer" with some compelling benefits for AI. They not only provide an integrating function but also add meaning to the data by capturing context, associations and relationships with other parts of the data.

We can use knowledge graphs to manage the relationships between data entities across different data models. Often these cannot be easily replaced because they are used for specific tools or operations," says Michael Weinhold, CTO for Siemens Smart Infrastructure. "Knowledge graphs establish an integrating data layer which can become meaningful input for AI tools."

For example, Siemens is developing knowledge graphs to combine data from digital buildings and smart grids so that AI applications can improve sustainability. With the aid of a knowledge graph, an AI application can integrate different building data, like energy consumption data from sub-meters, temperature profiles, occupancy rates and use this data to optimize a building's energy efficiency.

Similarly, Siemens uses AI and knowledge graphs to optimize gas turbines in the energy sector. An AI algorithm can recognize that components fail after a certain period of time using historical data. But with a knowledge graph, it can make more accurate predictions, by integrating contextual data, such as manufacturer details, operating temperatures, humidity and salt levels – a key factor in offshore oil and gas industry, for example.[1]

Michael May, Head of Company Core Technology Data Analytics & AI at Siemens, believes knowledge graphs are a major step forward in industrial AI. "Currently, many use cases are supported by a single sort of data, for example, speech or image data. The next stage, however, will be to provide speech and imaging data combined with a knowledge graph because this allows for more sophisticated opportunities to classify situations or inputs that could not be done with the single source of data. It combines learning from data with reasoning from background knowledge. This will drive a lot of progress.

Buying vs Building AI?

Respondents were asked to select all the ways in which their organization procures and develops AI. Some 70% say they do so by forming partnerships with AI specialists and consultants. A little over half this number (38%) have an in-house team building customized AI solutions; 31% get their AI built into vendor software; and 18% use off-the-shelf options (e.g. open-source models or AI services from cloud providers).

Half of respondents (52%) only use one of these strategies, and just 11% use three or more. This shows the relative immaturity of AI capabilities, with the majority of organizations lacking in-house teams to build customized solutions, and a mixed bag of strategies at play to access the benefits of AI.

[1] https://new.siemens.com/global/en/company/stories/research-technologies/artificial-intelligence/artificial-intelligence-industrial-knowledge-graph.html

2. Operations to strategy: the growth of AI everywhere

Organizations are using AI to make sense of vast internet of things datasets, while edge computing is helping to embed automated intelligence into the world. These twin trends will drive greater predictive power, more autonomous machines and richer simulations.

A significant driver of AI is the growth of data gathered from machines and devices, i.e. IoT data. IoT data has many immediate operational benefits, driven simply by allowing two machines to 'talk' to each other and use the interaction to drive some logic (e.g. a truck remains in the yard; don't close the gate).

Collected together, however, large sets of IoT data can provide unprecedented situational awareness for organizations, and this can drive simulations, produce insights, and enable more accurate predictions. AI models can help in this regard by quickly generating useful decisions, ideas and forecasts, deriving value from the vast volumes of IoT data available.

As such systems are built, we can contrast their efficacy with the incumbent decision-makers: experienced humans. While people are not able to consider every data point, we can be remarkably good at making good decisions quite fast (often using shortcuts such as rules of thumb and intuitions we can't quite explain). When organizations have both of these potential decision-makers available, when would we choose to go with AI?

When would you give an algorithm control?

Let's imagine you lead an organization that needs to adjust a range of operational settings each day to optimize production.

Every morning a group of senior colleagues agree these settings, based on their assessment of how the day will unfold. Your performance data shows that these adjustments are sufficiently useful half (50%) of the time.

If AI could match this performance, would you use this to automate control of the settings? Or would the AI need to do better than the employee group? We asked respondents to imagine this scenario and asked them what level of performance would lead their organization to switch to AI.

On a purely rational level, switching at equivalent performance makes sense because you save the time and effort of the group of employees every morning[2]. However, only 10% of respondents would make the switch at this level. Close to half (48%) wanted to see AI achieve 60%, while two in five respondents would require 70% or higher.

We may be tempted to permanently use both AI and the employee group at the same time. But what if they don't agree? This would introduce yet another decision, potentially stalling the process. It is likely that one decision-maker will become dominant over time, in which case the other becomes redundant, and so efficient organizations will choose one or the other. (Also note that the same redundancy would occur if the two always agreed. With identical performance, it would be become potentially wasteful to keep both systems in place.)

In reality, we would expect many organizations to let the AI "shadow" the employee group, until everybody is convinced that it is safe and effective. Hopefully this consensus would be easy to establish. If it is not, organizations will need to pioneer new ways to resolve the issues that emerge when impressive AI model clash with experienced employees.

Understanding trust

The requirement for outperformance which our respondents wanted shows how our thinking around AI is not always as rational as we may expect and that we need to understand the role of trust and feelings in these decisions.

"AI models are becoming very complex and so we need to find new ways to make them easier to interpret and understand. This is very important to building trust in these systems."

[2] In this scenario the AI system is already in place, so capital investment is not part of the equation, only operating costs (e.g. energy costs, employee remuneration) and the opportunity cost (i.e. of having employees working on something else). Hence, respondents could reasonably deduce that the AI system would cost less than the employees time, but this was not explicitly stated (in order to limit any bias).

It also points towards how trust is often linked to explainability and the need to avoid so called 'black box AI'. Perhaps we would be more inclined to accept equal performance from AI if we understood how it arrived at its judgements.

"The trouble is, this is not so easy," says Sabine Erlinghagen, CEO of Digital Grid at Siemens. "AI models are becoming very complex and so we need to find new ways to make them easier to interpret and understand. This is very important to building trust in these systems. One way to do this is with visualizations designed to help us interpret and communicate the work a model is doing. Over time I think we will build better visual tools that help summarize the underlying patterns and then trust will build as we become more accustomed to understanding AI in these ways."

Digital twins and AI

In the scenario above, respondents imagined that the IoT data was incorporated into a digital twin that simulated all aspects of the operations. This fed into the AI model which could therefore base its decisions on simulations of the consequences.

This is particularly relevant to the next generation of AI applications because there is enormous potential in using digital twins and AI together.[3] For example, AI-driven simulations can greatly enhance product design processes by being able to explore, assess and refine a digitized version of a new design for a physical product. This can extend right through the product lifecycle, including prototyping, testing, component selection, manufacturing, packaging, service and maintenance.[4]

There is a natural synergy between digital twins and AI. "It is really exciting because it addresses one of the key problems for deep learning in the industrial domain: the excessive amount of data that you need to solve a problem," says May. "With a simulation environment, you get access to an unlimited data supply. This is especially useful for designing systems to cope with anomalies that might rarely occur in real data but can be produced on demand in simulations."

Looking forward to fast adopters

A fifth (20%) of respondents are 'fast adopters' – accepting 50–70% accuracy from an AI simulation and requiring this for less than six months before replacing the employee group.

Our analysis suggests this fast-adopter group is likely more confident than reckless. More have in-house teams building customized AI solutions (58%) than the average (38%). A high proportion also report that their organizations have access to all the skills needed to manage current AI-related safety risks (74%) and cybersecurity risks (68%) compared with the average (53% and 52% respectively). This suggests that fast adopters have the skills – and the confidence these bring – to implement a quicker AI deployment strategy.

"Over time I think we will build better visual tools that help summarize the underlying patterns and then trust will build as we become more accustomed to understanding AI in these ways."

[3] https://new.siemens.com/global/en/company/stories/industry/the-digital-twin.html
[4] https://www.cxotalk.com/video/how-use-digital-twin-ai-improve-manufacturing

3. The rise of smart data exchanges

A significant number of next-gen AI breakthroughs will depend on intelligent, selective, agile data exchange between organizations that have rarely shared information before.

"AI is about generating value from data - it is driven more by data than actually by technology," says Norbert Gaus, Head of R&D for Digitalization and Automation at Siemens.

Many new and more advanced AI applications could be developed with wider access to new data types. This makes it important that some sources of potentially game-changing data are locked away from us. Most of these locked sources are generated beyond the walls of our own organizations, where access is often not easy – or even impossible. In our survey, only 37% of respondents say they can access external datasets without difficulties caused by their organization's internal policies, while just 43% are free from regulatory or legal barriers to external data access.

A lot of the time, organizations are not certain of the benefits that might emerge from trying to overcome these difficulties. But as Weinhold explains: "We need to be open to exploring data to derive solutions we cannot foresee. We should not only try to understand what data is needed to solve a problem, we should also analyze what kind of information can be derived from data, and then where this information could be beneficial."

As more organizations espouse this philosophy, we need to find smarter modes of data exchange. Smart data exchanges have the potential to facilitate decision-making across an entire supply chain, product lifecycle, customer journey, international enterprise, or any other product of multiple organizations.

Deliberating data-sharing

To investigate the willingness to participate in a smart exchange, respondents were asked what kinds of organizations might be considered for mutually beneficial data-sharing agreements.

Respondents considered one of their organization's most important and valuable data sets and were told that sharing subsections of this data set with another organization would lead to a significant increase in profitability. These subsections did not contain intellectual property or trade secrets.

How likely is a data-sharing arrangement? The results varied greatly by counterparty. Respondents report that they would be most likely to sign such agreements with the manufacturer of their machinery, vehicles or assets (76%), with a similar proportion likely to sign with key suppliers of raw materials or inputs (74%).

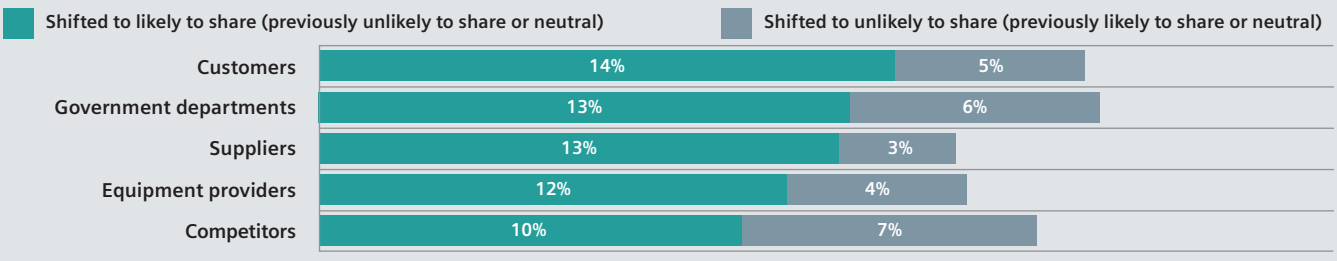
This reflects a typical business attitude towards cooperation with groups with common interests. It is a different picture when respondents imagine counterparties with whom they have a potential conflict of interest. For example, for our respondents, customers (40%), government departments (28%), and competitors (19%) all make far less attractive parties to a data-exchange agreement.

Blockchain exchange vs. human governance

In the scenario above, respondents imagined that the prospective agreement established suitable governance processes and that named individuals were appointed to control the data-sharing process. To evaluate the importance of these named individuals, we invited respondents to imagine the same scenario with one key difference: less human involvement. Instead, a blockchain system would ensure that only the specific organization in the agreement has access to the data, and that they can access only the agreed subsections. Would this increase or decrease the likelihood of an agreement?

We found it had both effects among our respondents, and while blockchain converted more towards sharing than against it, the picture is still mixed. "My observation is that, at this moment, most organizations would like to see human governance around data-sharing, particularly where data-sharing is only for specific purposes and with specific entities," says Ralf Michael Wagner, COO MindSphere. "However, as data-sharing becomes more natural, I think this will change over time. It remains pretty new in the industrial world and people need to get more acquainted with it and realize more benefits before they will be comfortable with some kind of smart automation to govern data-sharing."

The addition of blockchain, and reduction of human involvement prompted some respondents to reverse their decisions in our data-sharing scenario



4. Digital collaboration: when humans meet AI

Our machines, workstations, vehicles, buildings and equipment are starting to make decisions and take actions without our explicit direction, moving from being passive tools to active agents.

Imagine you are the boss of a busy factory. Your newly installed AI model (Maintain-AI) recommends immediate high-cost refurbishment work on important machines.

This is not good news. It will require extensive service/production downtime but Maintain-AI estimates that delaying the work will quickly increase the risk of a much more costly and disruptive repair.

You take Maintain-AI's signal very seriously. Trained on the machine manufacturer's 20-year performance dataset, it outperformed your best people in a year-long pilot.

Your head of operations adamantly disagrees with Maintain-AI's assessment: "We do not need any of this work done for at least a year! I inspected these machines myself and Maintain-AI clearly can't see what I can see. It is way too risk averse; it will waste a lot of money on parts and delay a lot of orders."

All things being equal, would you put your faith in Maintain-AI or trust your head of operations?

Attitudes to human vs AI decisions

From our survey respondents, 56% believed their organization would side with Maintain-AI compared with 44% for the head of operations. The decision shows both a developing respect for the power of AI and a similarly strong bias towards human experience. Organizations should be aware of this when they introduce AI into the workplace.

Human-AI collaboration is starting to develop in many industrial sectors. Collaborative robots, or 'cobots' work directly alongside humans, rather than behind safety barriers. For example, at RNB Cosméticos, a Spanish cosmetics manufacturer, cobots and employees together package over 350 different items at a rate of six per minute.[5]

In the future, more advanced cobots with artificial vision and microbiology abilities could potentially assist in other areas of the factory.

Virtual vs physical AI colleagues

We asked respondents what they thought the most common attitude would be from their organizations to the potential adoption of two kinds of autonomous AI "colleagues" (i.e. advanced AI systems that would function similarly in some ways to human colleagues, making independent decisions and acting autonomously).

Respondents reported that their organizations would be more open to adopting virtual AI colleagues (e.g. specialist AI assistants, AI analysts, AI market traders) than physical AI colleagues (e.g. robots; or autonomous vehicles and machines).

Averaged together we find that close to two-fifths (39%) expect enthusiasm for AI colleagues, while one fifth (20%) would expect resistance from their organization.

It should be noted our survey sought the opinions of those with responsibility, knowledge or involvement in their organization's AI projects. As such, our sample does not necessarily represent the overall views of the industries we covered. It is likely to mean that we see more enthusiasm and less resistance from our sample than from the wider population of senior industrial leaders and professionals.

To implement AI that is advanced enough to work more like a colleague than a computer or machine, organizations will need to develop new measures to help employees adapt, whilst ensuring that the right processes and governance are in place. Several factors are important here, but in our survey, safety and cybersecurity were most salient when our respondents considered their organization's attitude to both virtual and physical AI colleagues. This is explored in the next section.

Twice as much enthusiasm for AI, compared to resistance

[5] https://www.universal-robots.com/case-stories/rnb-cosmeticos/

5. Managing AI safety concerns

Many use cases for next-gen industrial AI are expected to make workplaces safer and more secure. Others will require us to trust AI with responsibilities we have only ever given to humans. In these cases, AI applications will need to win the confidence of decision-makers, while organizations will need to develop new risk and governance frameworks.

In many industrial organizations, bad decisions can have much more serious consequences than in other sectors. Thousands of people can be left without a train to work; millions of dollars can be lost if machinery overheats; slight changes in pressure can lead to an environmental catastrophe; and innumerable scenarios can lead to loss of life.

This makes it significant that a sizable proportion of respondents (44%) believe that, over the course of the next five years, an AI system will autonomously control machines that could potentially cause injury or death. Even greater numbers (54%) believe that AI will, within the same period, autonomously control some of their organization's high-value assets.

It is interesting is that our expectations of machines – and the forgiveness we're prepared to offer to machines making mistakes – are much lower than for humans. "We are quite used to people being prone to failure, but we expect machines not to make mistakes," Kress says. "If we hand something over to machines, we expect it to be significantly better." This is something we see in the approach most jurisdictions have to autonomous cars, which will need to achieve a much higher standard to get licensed than human drivers need to attain.

So, the advance of AI can only proceed with a strong focus on governance and risk, particularly around safety and cybersecurity. There are also concerns around ethics, and whether AI will do the right thing with its added 'responsibility'.

"From my point of view, I think it's good. We need people to be able to trust AI, and so this work is critically important," says May. "At the same time, we must not block progress. If we get regulation and legislation which is not really fit for the task, then it could overshoot and stifle the benefits AI offers. Yes, we need guidelines, yes, we need to be responsible when working with AI, but we need to do it in a smart way."

Improving safety and cybersecurity

It is important to remember too that AI is often applied to improve safety and cybersecurity. Indeed, many report that AI has already prevented safety incidents (44%) or protected their organization from cybersecurity threats (47%).

"AI can not only help us prevent emergencies, for example by alerting us to failing assets ahead of time, but when emergencies do occur, AI can also help suggest responses in real time that we may not think of, and these could help limit damage or even save lives," says Erlinghagen.

Mediating AI ethics

Are AI-driven automation systems capable of making unethical decisions? Some 45% of respondents say their organizations have concerns about this. Nearly half (48%) say their organization is concerned about AI-driven automation systems making cold, utilitarian decisions that ignore human emotions.

Getting the best out of the next generation of AI will involve making challenging refinements around what AI is supposed to do, what it is not allowed to do, and what is appropriate for AI-driven systems in situations that present ethical dilemmas or involve human emotions.

"AI can not only help us prevent emergencies, for example by alerting us to failing assets ahead of time, but when emergencies do occur, AI can also help suggest responses in real time that we may not think of, and these could help limit damage or even save lives."

Conclusion

These are still early days for industrial AI, but it has built significant momentum. The majority (53%) of organizations surveyed have seen AI make a significant positive impact, with 42% moving easily from pilot to full-scale implementations. More organizations in the Asia-Pacific region are keen to use as much AI as possible (69%) than those from other regions (overall average, 59%). But industrial leaders have experienced disappointments too. For 42% of respondents, AI applications have failed to live up to the hype generated by the media.

Over the coming years, there is no doubt that use cases will continue to mature and grow more sophisticated. As our machines, vehicles and buildings make decisions and take actions, this presents exciting opportunities, but it must be managed prudently. Bad decisions in industrial sectors can potentially cause equipment failures, financial losses, environmental damage, and risk human health and safety. We believe that industrial AI can only advance with a strong focus on governance, safety and cybersecurity.

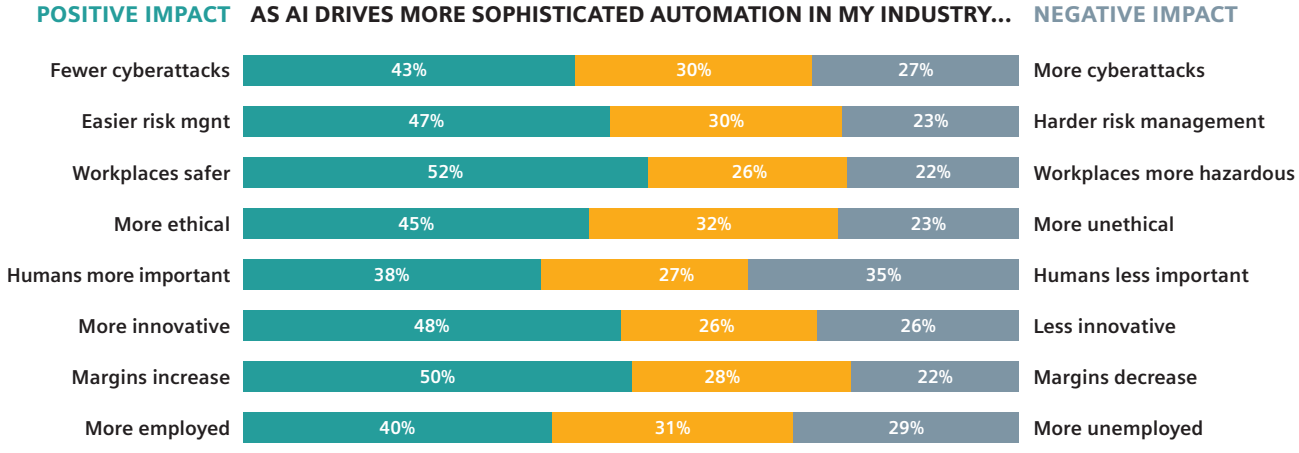
Industrial AI will need to become more sophisticated to be given responsibility over critical systems, and often this will be driven by new approaches to the way data is managed, generated, represented, and shared. One example is knowledge graphs, which capture the connections between different datasets, and thereby enable AI applications to infer meaning from data. Another is the data from Internet of Things and edge devices, which will help achieve new levels of situational awareness and real-time insights.

This research has identified concerns and challenges relating to industrial AI but these are outweighed by a sense that industrial organizations will overcome barriers and realize a variety of positive impacts from the next generation of industrial AI.

Indeed, overall, our survey paints a bright outlook. A significantly greater proportion of respondents believe that, as AI drives more sophisticated automation, this will result in more people being employed (40%) than left unemployed (29%). The research also found that leaders are anticipating fewer harmful cyberattacks, easier risk management, more innovation, higher margins, and safer workplaces.

These are encouraging results, which should inspire more leaders to design their future enterprise with AI as a key component. This is where we may see some of the most interesting changes, as AI-driven automation, or decision-making, is introduced to work alongside human workers. This will create new dynamics in the workplace, and it is incumbent on today's leaders to pioneer new structures, roles and teams that can thrive as a result. Success may well depend on balancing human intuition, ingenuity and emotional intelligence, with the expanding cognitive efficiency of next-gen industrial AI.

The industrial world expects more positive than negative impacts from AI driven automation

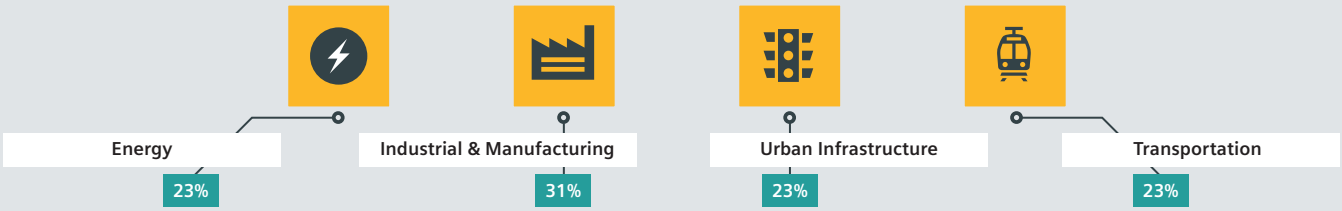


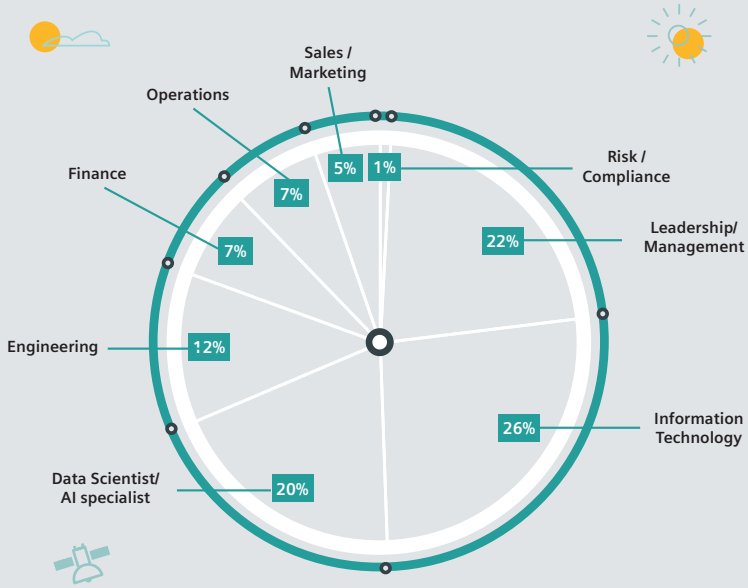
About the research

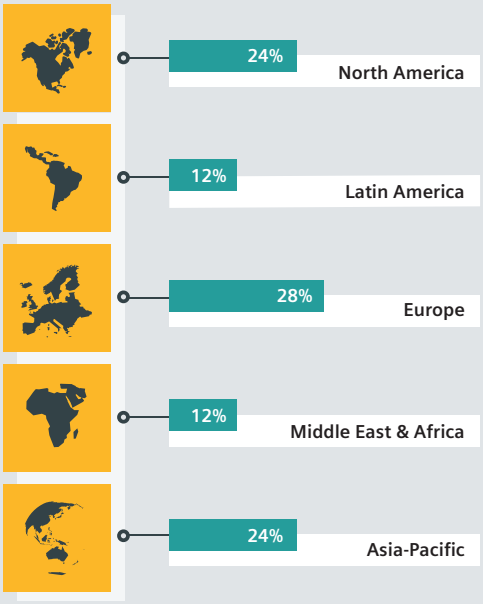
Siemens, and our research partner Longitude conducted primary research[6] into the uses, attitudes, and outlooks for AI in industrial organizations. We surveyed 515 senior business leaders in the energy, industrial/manufacturing, urban infrastructure, and transportation sectors.

In order to qualify for the survey, respondents needed to be responsible for, involved in, or knowledgeable about their organization's existing or planned use of AI and related technologies, strategies, budgets, and applications.

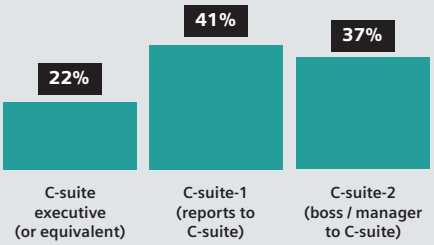
The research included respondents from North America, Latin America, Europe, the Middle East and Africa, and Asia-Pacific and was concluded in September 2019. All respondents were from organizations with an annual revenue of at least $100 million.

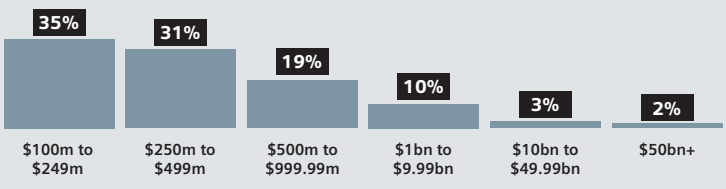






23%	Responsible for leading organisation's use of AI
37%	Involved in implementing organisation's use of AI
40%	Knowledgeable about organisation's use of AI





Next-Gen AI Manufacturing/ Industrial Sector

siemens.com/innovation

Next-Gen AI: The Star of Industry 4.0

For decades, heavy industry companies – those in manufacturing, engineering, metals, textiles, chemicals, and related sectors – have pioneered advanced automation and analytics to boost efficiency, safety, profitability, sustainability, innovation, strategy and more.

Now, they find themselves at different stages in terms of their integration of physical and digital assets and their use of sensors, connectivity, robotics, computing power, and the operational models and innovations that combine human ingenuity and automation. These are the elements of the so-called Industry 4.0.

But among that cast of elements there is a principal player. Artificial intelligence (AI) is the tool that is likely to do the most to change the way industrial companies actually operate. It can introduce increasingly human-like, adaptable capabilities, and help us make sense of the trillions of bytes of data collected by industrial companies from machines, processes, assets, markets, and the environment.

To what extent are industrial companies benefiting from AI now? How quickly will organizations change to accommodate more AI-driven operations? And how will industrial companies deal with issues of trust, governance, safety, and cybersecurity?

To answer these and other questions, we conducted a survey of 515 senior leaders who have some responsibility for, involvement in, or knowledge about their organization's existing or planned use of AI. Here, we discuss what we learned from the 158 industrial sector respondents; the findings for all industries are in our Next-Gen Industrial AI report.

AI in a post-covid world

When this research was commissioned, there was a lot of hype around the potential of consumer AI, and fewer insights available on industrial AI. While we at Siemens, with over 30 years' experience in industrial AI, are no strangers to this field, we wanted to learn more about the experience of other organizations. This research sought to uncover the benefits and barriers of industrial AI applications, and to highlight its potential, especially when combined with other technologies like IoT and digital twin. Suddenly the world is a different place. However, as organizations seek to recover, rebuild and adapt in a post-covid environment, the potential of industrial AI is more relevant than ever.

So far, industrial companies have seen only modest benefits from AI, with leading use cases providing a major or moderate benefit for less than a third of companies. Those use cases include systems that intelligently optimize systems automatically (30% have experienced a major or moderate benefit), provide market or system forecasts (30%), automate and/or improve quality control (30%), improve existing products and services (29%), identify risks/issue warnings (27%), and predict asset maintenance needs (25%).

But respondents expect significantly greater benefits to be realized quite soon. In all the cases above, between 77% and 84% expect a major or moderate benefit in just three years' time. Part of this expected growth will be down to the increasing accessibility of AI, particularly for companies that do not have specialist AI capabilities.

Only 44% of respondents have an in-house team that is building customized AI-driven solutions, but many are taking advantage of products with AI functionality. For example, neural network processors are being built into machine control modules, which means that companies can buy 'off-the-shelf' visual or auditory discrimination tools (for example for quality checks or process monitoring).[1]

New opportunities where context matters

AI applications are developing rapidly, and as industrial companies increase their adoption, the next generation of innovations and applications will create new opportunities.

Much of that innovation is driven by advances in the way data is managed, generated, represented, and shared. "AI is about generating value from data," says Dr Norbert Gaus, Head of R&D for Digitalization and Automation at Siemens. "It is driven more by data than by technology."

So sometimes it will be advances in how we represent, blend and manage data that will lead to AI breakthroughs. Knowledge graphs are one example. Often visualized as giant spider-diagrams, knowledge graphs capture the meaning of, and relationships between, items in diverse data sets.

"Knowledge graphs add context to the data you're analyzing," says Gaus. "For example, machine data can be analyzed in the context of design data, including the tasks the machine is made for, the temperatures it should operate at, the key thresholds built into the parts, and so forth. To this we could add the service history of similar machines, including faults, recalls and expected inspection outcomes throughout the machine's operational life. Knowledge graphs make it much easier to augment the machine data we use to train AI models, adding valuable contextual information."

[1] https://press.siemens.com/global/en/pressrelease/artificial-intelligence-simatic

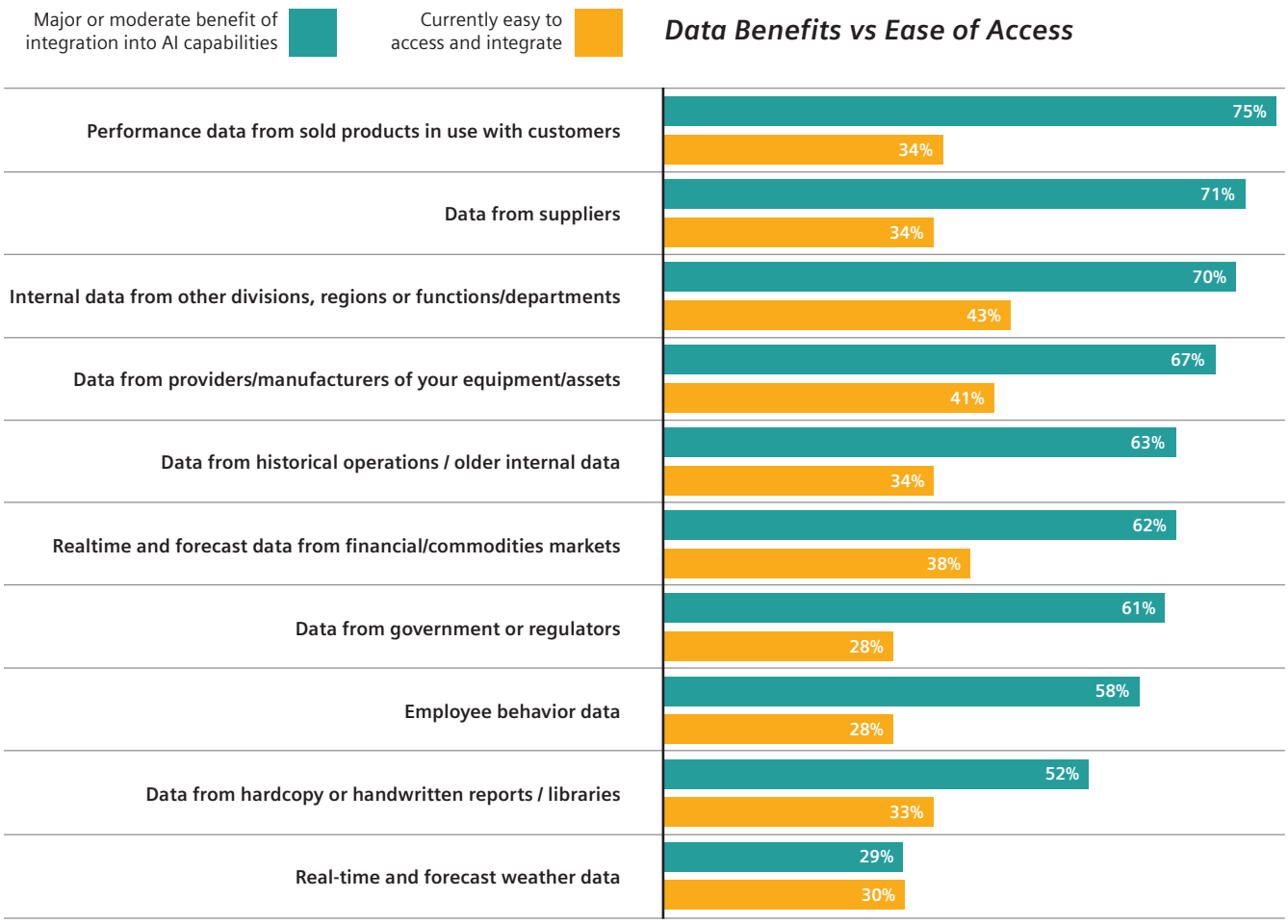
What kind of contextual data would be most useful? Performance data from sold products in use with customers (75%) came out on top in our survey, followed by data from suppliers (71%), internal data from other divisions, regions or departments (70%), and data from manufacturers of equipment or assets (67%).

AI is a powerful tool

A company that uses knowledge graphs to bring these kinds of data together would be able to train a single AI model with information about the life of previous products, operational inputs, variables, and dependencies. The AI model could identify valuable patterns and clusters in this diverse dataset, which could then drive better predictions, useful ideas, new efficiencies, and more powerful automation.

Even our respondents' top choice alone could be transformative for AI applications. Performance data from sold products can complete feedback loops that have historically been hard to close.

"This would help us understand, for example, whether something was poorly designed, whether something went wrong in the manufacturing process, or if customers are using the product in unforeseen conditions," says Gaus. "Perhaps the design makes manufacture complicated, which affects durability in certain conditions. Having these feedback loops automatically flow back from the whole product lifecycle could help us to isolate issues and improve products. For some organizations, this could be game-changing."



AI and the big decisions: what would you do?

AI's advance, however, brings with it new challenges for industrial companies. One of the most interesting is how much confidence to have in the results, insights and decisions that are generated by AI – especially when the stakes are high.

To explore this, we asked the survey respondents to imagine that their organization had installed a brand-new AI model, called Maintain-AI, which had been trained on 20 years of performance data from the manufacturer of their machinery. We told them that Maintain-AI had recommended immediate lengthy, high-cost, disruptive refurbishment work on important machinery, but that their head of operations – with 20 years of industry experience – strongly disagrees. Having personally inspected the machinery, the head of operations says the work would be an unnecessary waste of time and money.

The 158 industrial company respondents considered this scenario, and a modest majority (58%) said that their organization would side with Maintain-AI, which suggests many are open to trusting in the results of AI-driven analysis.

It is important to point out, however, that we told respondents that Maintain-AI had outperformed the organization's best people in a year-long pilot prior to the refurbishment recommendation. With that in mind, the fact that a sizeable group (42%) still opted to go with the head of operations is more concerning: it indicates a potential bias against AI that could stop some companies from progressing.

Falling barriers, rising benefits

The relatively high proportion that opted not to trust AI in our hypothetical scenario could be attributed to industrial companies' top barriers to progress with AI. Cybersecurity risks and liability risks are both cited as major or moderate barriers by 80% of respondents. However, things may be about to change because both these barriers are expected to fall within the next three years – to 52% and 40% respectively.

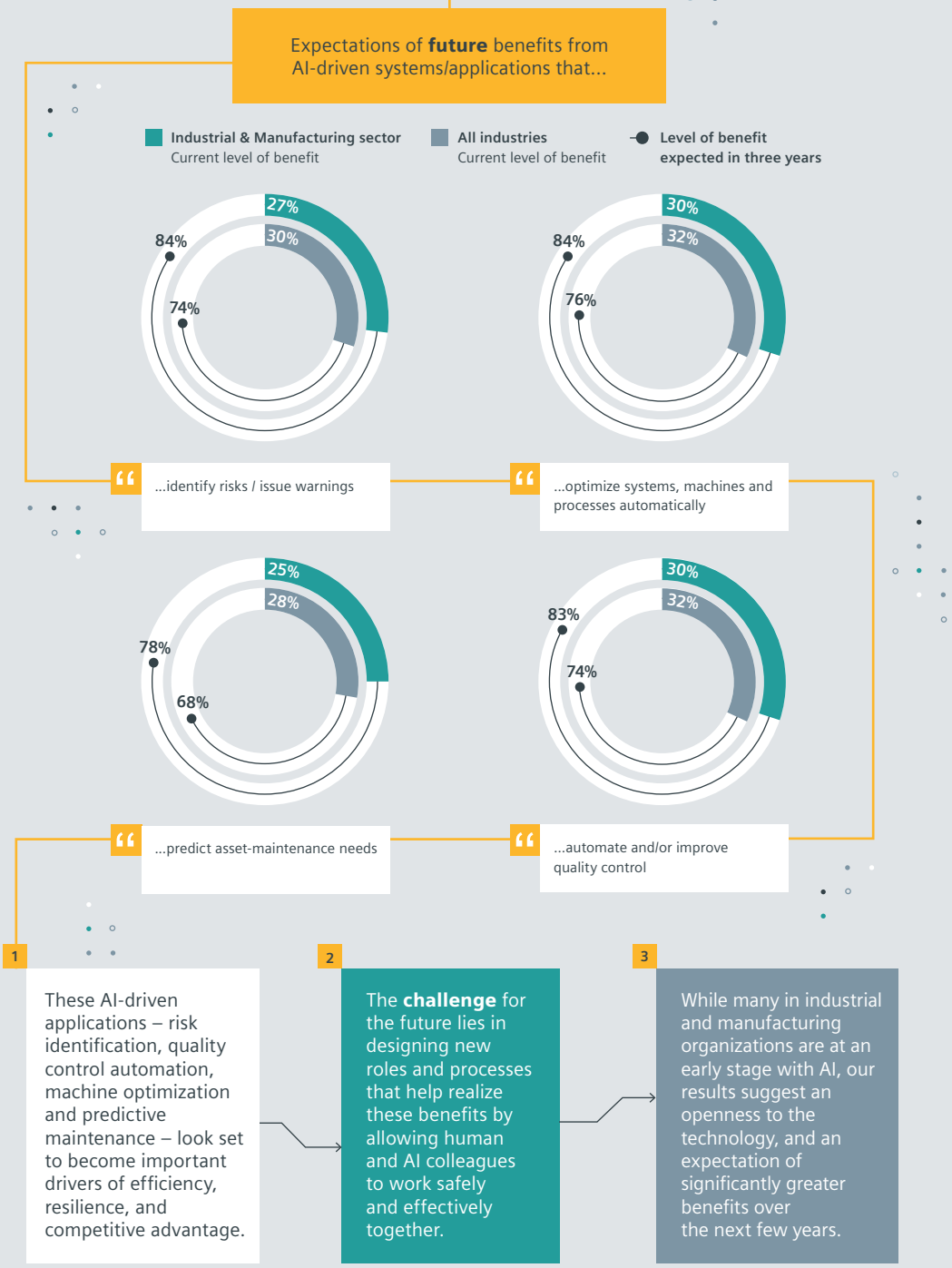
Overall, our research shows that the industrial sector is positive about AI, with a clear majority (60%) reporting that their organizations are eager to use as much AI as possible. With barriers expected to fall as swiftly as benefits are expected to rise, we may be about to see the next generation of AI emerge as the star of Industry 4.0.

What is AI?

In this report, and the research that supports it, 'artificial intelligence' and 'AI' refer to a broad spectrum of methods or technologies that perform tasks which would normally require functions of human intelligence such as learning, judging, and problem-solving. This is more in keeping with the contemporary business understanding of AI than any technical or academic conventions.

Overall, our research shows that the industrial sector is positive about AI, with a clear majority (60%) reporting that their organizations are eager to use as much AI as possible.

AI IN MANUFACTURING AND HEAVY INDUSTRY



ABOUT THE RESEARCH: Siemens and our research partner Longitude conducted primary research into the uses of, attitudes to, and outlooks for AI in industrial organizations. We surveyed 515 senior business leaders in the energy, industrial/manufacturing, urban infrastructure, and transportation sectors. Of the 158 industrial company respondents, 64.6% were from the manufacturing sector (e.g. engineering, electronics, automotive, food/beverage, apparel, aerospace); 28.5% were from heavy industry (e.g. metals, chemicals, textiles, paper); 5.7% were from pharmaceuticals and life sciences; and the remaining 1.2% were from agriculture and mining. In order to qualify for the survey, respondents needed to be responsible for, involved in, or knowledgeable about their organization's existing or planned use of AI and related technologies, strategies, budgets, and applications. The research included respondents from North America, Latin America, Europe, the Middle East and Africa, and Asia-Pacific and was concluded in September 2019. All respondents were from organizations with an annual revenue of at least $100 million.


SIEMENS
Ingenuity for life
Next-Gen Industrial AI
Energy Sector
siemens.com/innovation

Next-Gen AI in Energy: A Tool for Transition

Artificial intelligence (AI) is starting to play a powerful role in the energy sector. It is enabling organizations to harness data to innovate, become more efficient, and adapt to the energy transition.

But just how is the energy sector embracing AI, and what are energy leaders' attitudes toward the technology? What do those leaders expect from the next generation of AI? How are organizations responding to the changes AI is driving? And how is AI changing the workplace?

To answer these questions, we conducted a survey of 515 senior leaders who are responsible for, involved in, or knowledgeable about their organization's existing or planned use of AI. Here, we discuss what we learned from the 117 energy sector respondents; the findings for all industries are in our Next-Gen Industrial AI report.

Many energy firms in the research are already transforming their operations using AI. The top way they are using it is for more intelligent automation of machinery and equipment, which was selected by 30% of respondents. That is followed closely by asset maintenance forecasts (28%) and the optimization of processes, machines, software, or tools (28%).

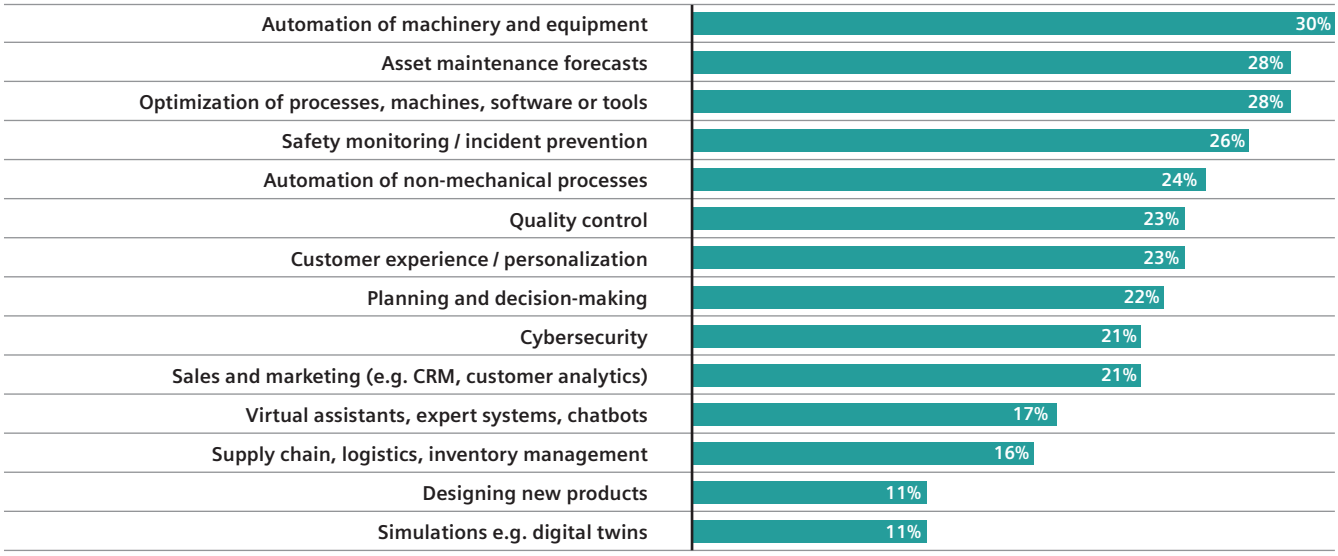
Opportunities to benefit from AI applications extend throughout the energy value chain. EDF energy, for example, is considering use cases for AI across its network, including for predictive maintenance at power stations, identification of components to support digital replicas of equipment, and better understanding customer usage patterns.[1]

Operation centers for power grids can use AI to classify disturbances and help them to decide on the best response. Meanwhile, engineers in the field can use AI to help establish the location and nature of faults – valuable insights that make remediation quicker, safer, and more efficient.[2]

AI in a post-covid world

When this research was commissioned, there was a lot of hype around the potential of consumer AI, and fewer insights available on industrial AI. While we at Siemens, with over 30 years' experience in industrial AI, are no strangers to this field, we wanted to learn more about the experience of other organizations. This research sought to uncover the benefits and barriers of industrial AI applications, and to highlight its potential, especially when combined with other technologies like IoT and digital twin. Suddenly the world is a different place. However, as organizations seek to recover, rebuild and adapt in a post-covid environment, the potential of industrial AI is more relevant than ever.

How/where does your organization currently use AI? (Energy respondents only)



[1] https://www.computerworld.com/article/3426809/how-edf-wants-ai-to-optimise-its-nuclear-power-stations-and-the-smart-home.html
[2] http://www.epcc-workshop.net/images/Presentations/Session5/EPCC15-5-2_Discussion_Siemens_Apel.pdf

The future of forecasting

A key area of interest in the coming years will be how AI can help electricity grids to integrate renewable sources.

"Forecasting the supply and demand of energy has always been important, but it has become more complex with the introduction of numerous, distributed, renewable energy sources with fluctuating production," says Rolf Apel, Principal Key Expert at Siemens Smart Infrastructure. "In the past, it was just the load that depended on the time and the weather primarily. Now, the energy flow is influenced by many new variables, including home energy storage, roof-top solar, electric cars, offshore wind farms, and many others."

All of this makes accurate prediction much more complex – at least for human minds. AI systems, however, are well-suited to this kind of task, and are maturing at a similar pace to the growth of renewable energy.

Another challenge for today's power grids is the decrease of inertia, which requires better monitoring of transient processes, in order to detect emerging instabilities early and initiate appropriate countermeasures. AI can also provide good support in this area. The DynaGridCenter in Germany is an example of such a pioneering system. This transmission control center uses intelligent control systems and digitalized substations to manage the dynamics of a grid that has multiple inputs from renewable sources, as well as the increasing application of power electronics.[3]

"The DynaGrid system uses AI elements to semi-autonomously control transmission flows and optimize the network," says Michael Weinhold, CTO of Siemens Smart Infrastructure. "It is currently being tested, in parallel with a conventional control system, to successfully manage and optimize load flows across the transmission system in real time."

What is AI?

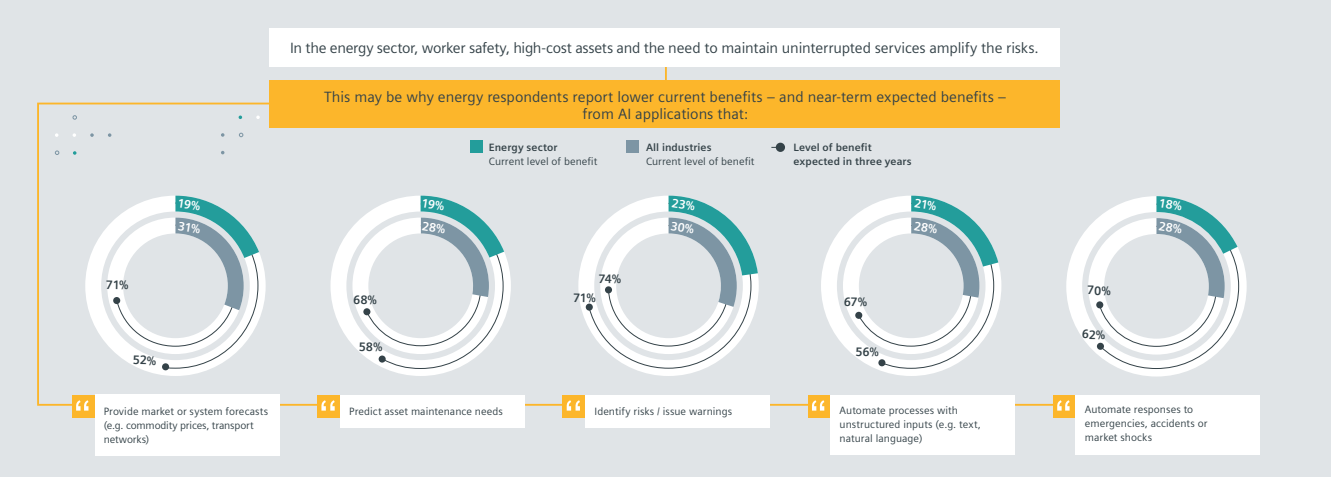
In this report, and the research that supports it, 'artificial intelligence' and 'AI' refer to a broad spectrum of methods or technologies that perform tasks which would normally require functions of human intelligence such as learning, judging, and problem-solving. This is more in keeping with the contemporary business understanding of AI than any technical or academic conventions.

AI adoption gains momentum

Energy firms are in the early stages of AI adoption. Only a minority of respondents in our survey (39%) say that their organization has easily moved from AI pilots to full-scale implementations. However, a higher percentage say they are seeing results, with half saying that AI has already had a significant positive impact on their organization. Even more (55%) say their organization is eager to use as much AI as possible.

But the energy sector is cautious about adopting new technology, and that is understandable given the importance and value of energy assets and the risks associated with them. In our survey, however, energy respondents' top barrier to further adoption of AI is resistance to change/ conservatism (selected by 85%).

That inertia can be part of organizational culture, but when it comes to AI it can also be fueled by more specific issues with the technology. Since AI can help us to intelligently automate processes, some see it as a threat to their value in the organization. Others may have difficulty trusting AI with important assets and decisions.



[3] https://new.siemens.com/global/en/products/energy/topics/dyna-grid-center.html

Energy leaders are divided: can they trust AI?

To explore these factors, we created a hypothetical scenario for our respondents to consider. This was designed to reveal inherent biases toward AI-related change, and is a valuable exercise for us all.

Imagine that your organization has installed a brand-new AI model, called Maintain-AI. It has been trained with 20 years of performance data from the manufacturer of your machinery. On assessing your machines, Maintain-AI recommends immediate high-cost refurbishment work on mission-critical equipment. The work will require extensive production downtime, which would be disruptive and costly.

But there's resistance. Your head of operations, who has 20 years of industry experience, is not happy with Maintain-AI's conclusions. In fact, they strongly disagree. They have personally inspected the machinery and see no issues, and stress that making the recommended repairs would waste money.

We put this scenario to the 117 senior energy industry professionals in our survey, and the results reveal a clear split. While a small majority (56%) say they would side with Maintain-AI, 44% would listen to their head of operations.

This points to a looming challenge for energy companies because in this scenario question we also told respondents that Maintain-AI had outperformed the organization's best people in a year-long pilot prior to the refurbishment recommendation. With that in mind, the fact that a sizeable group (44%) still opted to go with the head of operations is more concerning: it indicates a potential bias against AI that could stop some companies from progressing.

A safer sector with AI?

This issue of bias comes to the fore when we look at situations of high value, importance, or risk. For the energy industry, these situations are both common and strong contenders for AI-driven automation.

Nearly half of the energy executives we surveyed (48%) say that within the next five years an AI system will autonomously control assets in their organization that could, as a result of error or accident, cause injury or death.

And AI is expected to make the energy industry safer over time. Respondents are much more likely to say that their workplace will become safer (56%) as AI drives more sophisticated automation, than more hazardous (23%). In addition, a sizable proportion (42%) say that AI *has already* prevented safety incidents at their organizations.

"More advanced data analytics and AI will enhance safety and security in energy systems," says Weinhold. "AI can help us to make data-driven decisions quickly for many contingencies. For example, to react to critical situations, like a strong in-feed from renewables or a system fault, AI trained by simulations and analysis of hundreds of eventualities can rapidly generate the right countermeasures to keep systems running safely."

Cautious optimism for AI's potential

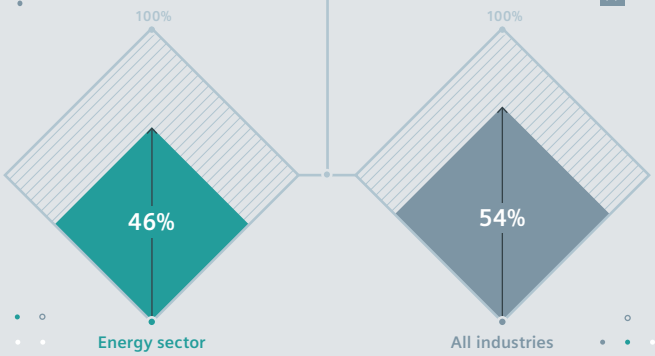
The energy industry is balancing several competing priorities as it transitions to a lower-carbon future. Decarbonization, decentralization, and digitalization are the most-cited challenges, and AI is part of that. But it is also a potential ally – a powerful tool that can help the energy industry adapt to decentralized, lower-carbon energy sources. Similarly, AI automation – perceived by some to be a hazard – will increasingly look more like an opportunity to make the industry safer.

Our research finds the energy industry divided on AI. For some, the technology has not yet proved its value and safety; but a small majority is already embracing the benefits of AI, and is exploring its potential with a balance of caution and optimism.

"AI can help us to make data-driven decisions quickly for many contingencies. For example, to react to critical situations, like a strong in-feed from renewables or a system fault, AI trained by simulations and analysis of hundreds of eventualities can rapidly generate the right countermeasures to keep systems running safely."

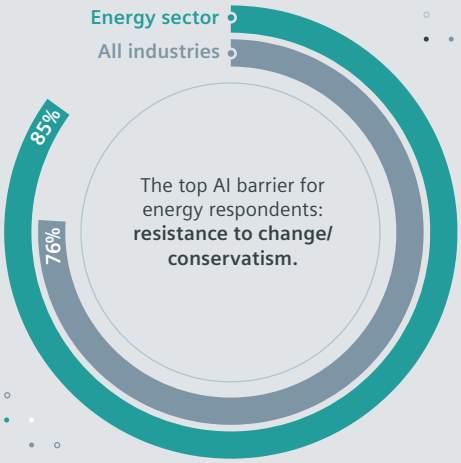
Even looking five years ahead, fewer than half of energy respondents think that their organizations are likely to give AI full control of any high-value assets within that timeframe.

"Within the next five years, an AI system autonomously control some of my organization's high-value assets"



Taken together, the results of our research show energy leaders are rational about AI's potential, while being cautious about its implementation.

Much of this caution is well-placed, given the importance, value and risks associated with energy assets. However, respondents report that there is an even more significant barrier to further implementation of AI...



While other barriers are also prominent (e.g. data integration, skills, safety, cybersecurity and funding), our research suggests that a cultural shift – towards embracing new ideas, models and processes – is needed in order to overcome these barriers and accelerate the benefits of AI applications in the energy sector.

ABOUT THE RESEARCH: Siemens and our research partner Longitude conducted primary research into the uses of, attitudes to, and outlooks for AI in industrial organizations. We surveyed 515 senior business leaders in the energy, industrial/manufacturing, urban infrastructure, and transportation sectors. Of the 117 energy industry respondents, 82.1% were from power generation organizations (e.g. operators of hydro, gas, wind, oil, coal, nuclear, biomass or solar power plants), and 17.9% were from electricity transmission and distribution organizations (e.g. power utilities, grid operators, distribution system operators). In order to qualify for the survey, respondents needed to be responsible for, involved in, or knowledgeable about their organization's existing or planned use of AI and related technologies, strategies, budgets, and applications.The research included respondents from North America, Latin America, Europe, the Middle East and Africa, and Asia-Pacific and was concluded in September 2019. All respondents were from organizations with an annual revenue of at least $100 million.


SIEMENS
Ingenuity for life
Next-Gen Industrial AI
Urban Infrastructure Sector
siemens.com/innovation

Next-Gen AI in Urban Infrastructure: Bringing Data to Life

It is the age of the Internet of Things (IoT) and urban infrastructure is more connected than ever. New technologies are driving innovation in design, development, and management: cloud computing, edge computing, 5G, sensors, and connected devices are all important components of the city of the future.

However, you could argue that artificial intelligence (AI) is the most transformative ingredient in the mix. AI is the element that makes digital smart, makes automation intelligent, and can turn incremental modernization into ground-breaking innovation.

To see why, consider what the IoT trend is doing to cities around the world: "An environment in which individually addressable devices communicate, via the internet, using a set of commonly understood communications standards and protocols; sharing data, responding to commands and even acting autonomously."

Together, those devices are generating staggering volumes of data. And it is AI that can help planners, construction firms, and policymakers to make sense of that data, get value from it, and build devices that can act autonomously.

So how are leaders in the infrastructure industry thinking about AI? What progress have they made? And what new challenges are emerging?

To answer these questions, we conducted a survey of 515 senior leaders, including 118 from organizations involved in the design, development and management of urban infrastructure (which we are calling the 'infrastructure industry'). Each respondent is responsible for, involved in, or knowledgeable about their organization's existing or planned use of AI. Here, we discuss what we learned from those 118 infrastructure industry respondents; the findings for all industries are in our Next-Gen Industrial AI report.

The infrastructure industry embraces AI

Our infrastructure respondents say that their organizations have only yielded modest benefits from AI to date, but they are significantly ahead of the other industries we surveyed.

The top three areas they say are currently offering their organizations major or moderate benefits are the automation and/or improvement of quality control (cited by 46%), the automatic optimization of systems (45%), and the automation of responses to emergencies, accidents or market shocks (45%). This compares with 21%, 22%, and 18% respectively for energy industry respondents, and 30%, 30%, and 20% for manufacturing and heavy industry respondents. That is a big difference.

However, all the industries we surveyed have quite similar levels of enthusiasm for AI in general: 59% of all respondents say their organizations are eager to use as much AI as possible. That proportion is only a little higher (62%) for infrastructure respondents. So the reason for the differences we've seen in benefits achieved could be down to the relatively lower intensity of barriers to AI development reported by infrastructure respondents.

The barriers to implementing AI at greater scale appear to be high across the board, but respondents to our survey expect many of these obstacles to drop sharply in significance over the next three years.

For infrastructure respondents, the barrier expected to fall away the sharpest is data integration and quality issues. Just 22% expect this to be a moderate or major barrier in three years' time, down from 63% currently. In fact, respondents have it falling from the fourth-ranked barrier today to the bottom-ranked barrier (of 11) by 2022.

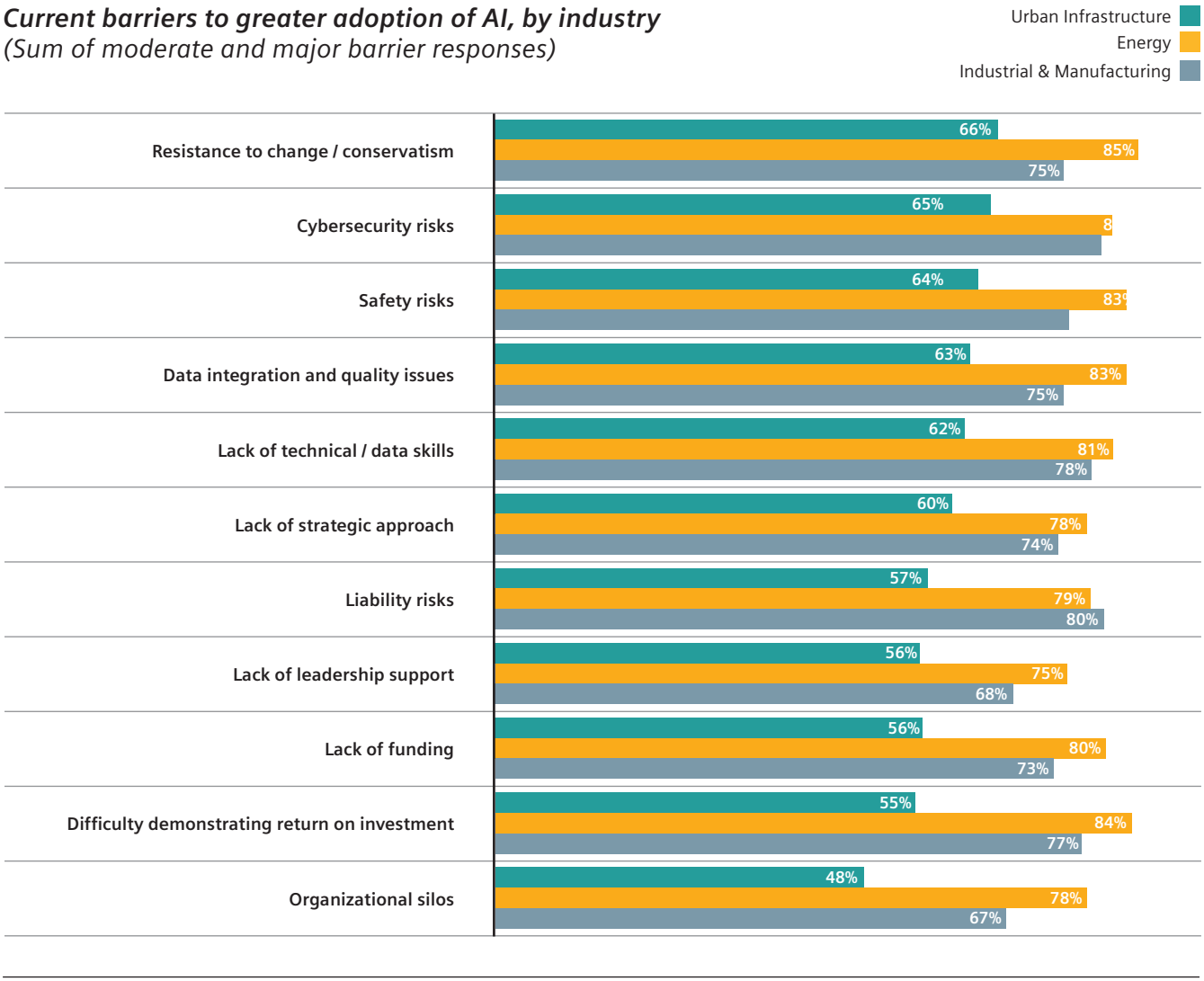
Why is the challenge of data integration and quality expected to ease off so rapidly? Much of it comes down to advances

AI in a post-covid world

When this research was commissioned, there was a lot of hype around the potential of consumer AI, and fewer insights available on industrial AI. While we at Siemens, with over 30 years' experience in industrial AI, are no strangers to this field, we wanted to learn more about the experience of other organizations. This research sought to uncover the benefits and barriers of industrial AI applications, and to highlight its potential, especially when combined with other technologies like IoT and digital twin. Suddenly the world is a different place. However, as organizations seek to recover, rebuild and adapt in a post-covid environment, the potential of industrial AI is more relevant than ever.

[1] https://new.siemens.com/global/en/products/buildings/contact/smart-building-whitepaper.html

Current barriers to greater adoption of AI, by industry
(Sum of moderate and major barrier responses)



in the performance and availability of computing power and storage, but there are also likely to be shifts in our thinking about data management and analytics.

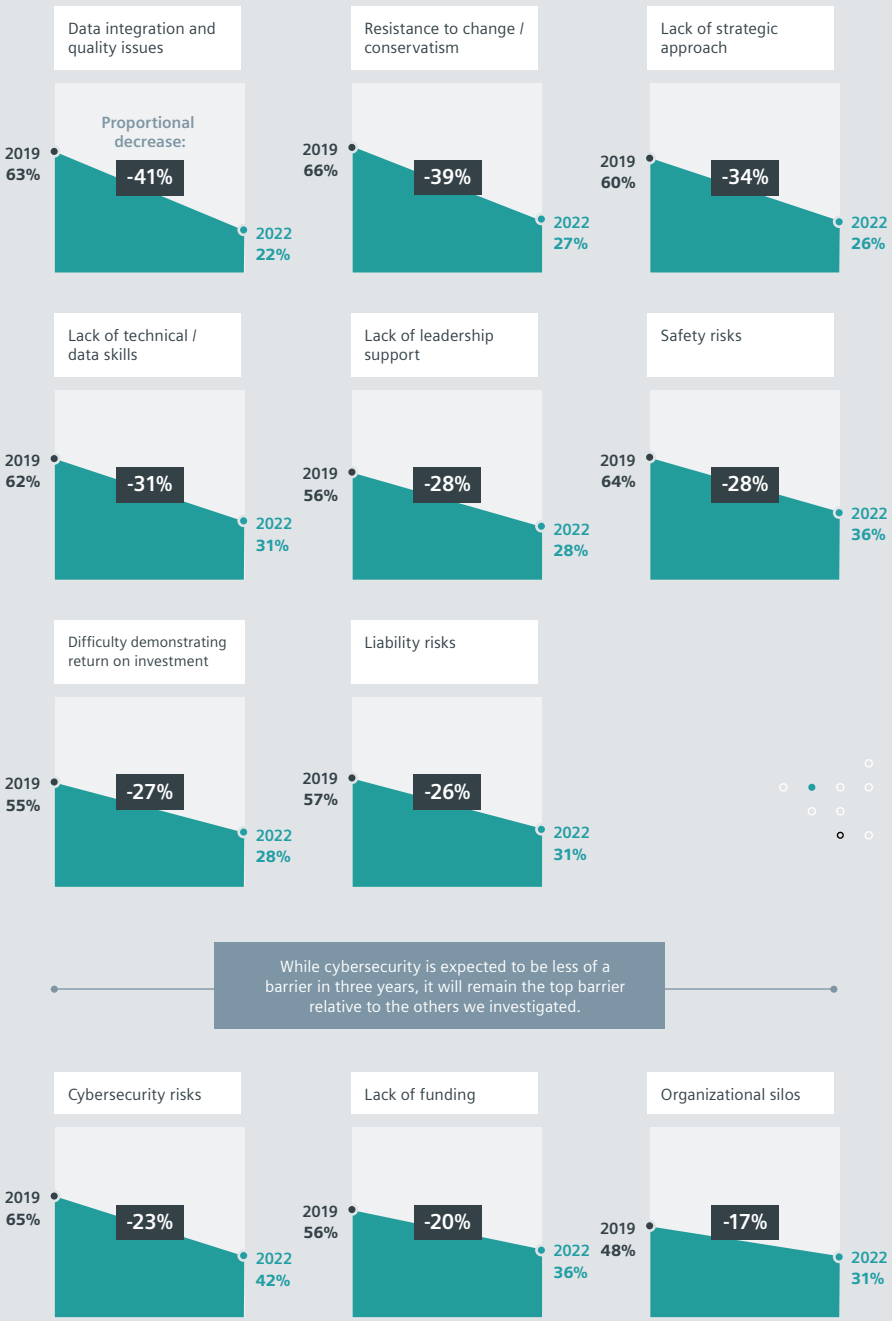
"Over the past 10 to 15 years there has been a trend of pulling all data together in one data warehouse and building a dashboard on top to get an overview of everything," says Gerhard Kreß, Vice President for Data Services at Siemens Mobility. "This can take years to achieve, because you need to normalize the data while you assemble it. It has never really worked because it takes too long, costs too much and does not cope well with change."

Instead, we will increasingly leave datasets where they are, and in their existing format. "You don't integrate it in the traditional sense, but add a layer on top that glues it together and makes it accessible," says Kreß. "This is attractive, because it saves a huge amount of time and effort, and data-owners do not need to give away control of their databases or make big changes to their data management models." This approach speeds up application development dramatically. The cost? It demands more computing power. But that is increasingly cheap and sustainable, so the trade-off makes business sense.

AI IN URBAN INFRASTRUCTURE

What are the significance of barriers (combined moderate and major) today and in three years time?

Major barriers, such as data integration and resistance to change, are expected to fall much more dramatically.



While cybersecurity is expected to be less of a barrier in three years, it will remain the top barrier relative to the others we investigated.

Awareness, anticipation, and autonomous action

AI can help the infrastructure industry to find important – often hidden – patterns in the growing torrent of IoT data from sensors, machines, assets, and all manner of devices located across our cities. This can lead to new insights, better decisions, more accurate predictions and more effective services.

AI can support greater automation by generating and executing intelligent responses to events in real-time. So assets such as power grids, bridges, pipes, and street lights will be able to autonomously adapt to conditions, communicate with the infrastructure around them, and optimize their own maintenance, safety, and resource consumption.

One example of AI creating value from multiple disparate datasets is in air-quality analysis and prediction systems. These draw on past weather and pollution data, plus live feeds from the city's IoT fabric (which provides, for example, data on moisture, sunlight, cloud cover, temperature, and levels of key pollutants).

Some systems also incorporate data that helps them adapt their predictions according to patterns recorded on different days of the week, months or years, including major city events, while continuously updating based on live data[2]. Why is all this useful? In some cities, forecasting air quality is critical to managing public health. And for all cities, understanding what affects air quality helps us to plan and regulate cities based on objective patterns, which should ultimately help us achieve cleaner air.

The smart city's data decoder

To what extent can AI help us improve urban infrastructure? It is already helping the industry to better understand and monitor urban systems, predict important changes, and deploy more intelligent and autonomous machines, assets, and devices. These benefits can support the major goals of any city – from reducing emissions to boosting economic competitiveness.

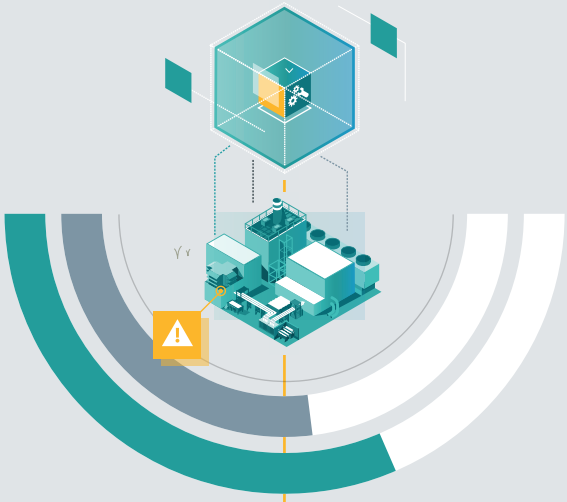
Ultimately, AI's transformative potential is limited only by the infrastructure sector's capacity to innovate, and that makes it the IoT era's most transformative technology.

What is AI?

In this report, and the research that supports it, 'artificial intelligence' and 'AI' refer to a broad spectrum of methods or technologies that perform tasks which would normally require functions of human intelligence such as learning, judging, and problem-solving. This is more in keeping with the contemporary business understanding of AI than any technical or academic conventions.

[2] https://new.siemens.com/global/en/company/stories/infrastructure/artificial-intelligence-improves-air-quality.html

Within the next five years, will an AI system autonomously control some of my organization's high-value assets?



63% Urban infrastructure

54% All industries

Overall, urban infrastructure respondents were found to be the best prepared (among the other industries surveyed) to access the benefits of AI, particularly in combination with existing IoT endeavors and developing Edge applications.

In fact, a strong majority...

62%

say their organizations are eager to use as much AI as possible (compared to 58% for all industries) and, with barriers falling, the next few years are likely to see many fascinating changes in how we manage, operate and automate infrastructure assets.

This is perhaps why, compared to other industries, significantly more urban infrastructure respondents are expecting some of their organizations' high-value assets to be autonomously controlled by AI systems within the next five years.

ABOUT THE RESEARCH: Siemens and our research partner Longitude conducted primary research into the uses of, attitudes to, and outlooks for AI in industrial organizations. We surveyed 515 senior business leaders in the energy, industrial/manufacturing, urban infrastructure, and transportation sectors. Of the 118 urban infrastructure respondents, 26.3% were from infrastructure construction/development; 24.6% from building or infrastructure management (e.g. facilities or real estate management); 23.7% from infrastructure-related professional services (e.g. engineering, consulting, architecture, planning, technology); 16.1% from public/government infrastructure development and/or management; 7.6% from data centers and industrial technology infrastructure; and 1.7% from water supply, sanitation, treatment, desalination, and flood defense. In order to qualify for the survey, respondents needed to be responsible for, involved in, or knowledgeable about their organization's existing or planned use of AI and related technologies, strategies, budgets, and applications. The research included respondents from North America, Latin America, Europe, the Middle East and Africa, and Asia-Pacific and was concluded in September 2019. All respondents were from organizations with an annual revenue of at least $100 million.

Next-Gen Industrial AI

Regional Spotlight: Europe

siemens.com/innovation

Next-Gen Industrial AI: Caution, Conservatism and Competition

Europe is well-positioned to be a world leader in the use of AI in industry, but the next generation of AI will create scenarios we've not encountered before – particularly in how AI and humans work together. Some of these scenarios not only require completely new processes, but also an important mindset shift: we have to be prepared to extend our confidence in digital capabilities to tasks that have only ever been assigned to people.

To investigate the shift toward the next generation of industrial AI, we conducted a survey of 515 senior leaders. Each respondent needed to be responsible for, involved in, or knowledgeable about their organization's existing or planned use of AI. Here, we discuss some of the findings from the 148 respondents in Europe; the overall findings have been published in our Next-Gen Industrial AI report.

Greater benefits are expected

Our Europe respondents are expecting a big increase in the benefits of AI over the next three years. These include using AI to automate quality control; to improve existing products; to automate responses to emergencies; and to identify risks. Each of these benefits is expected to benefit roughly twice as many organizations by 2022 as today.

That kind of progress would be impressive on its own, but what is interesting is that other regions – including North America and Asia-Pacific – are anticipating bigger jumps.

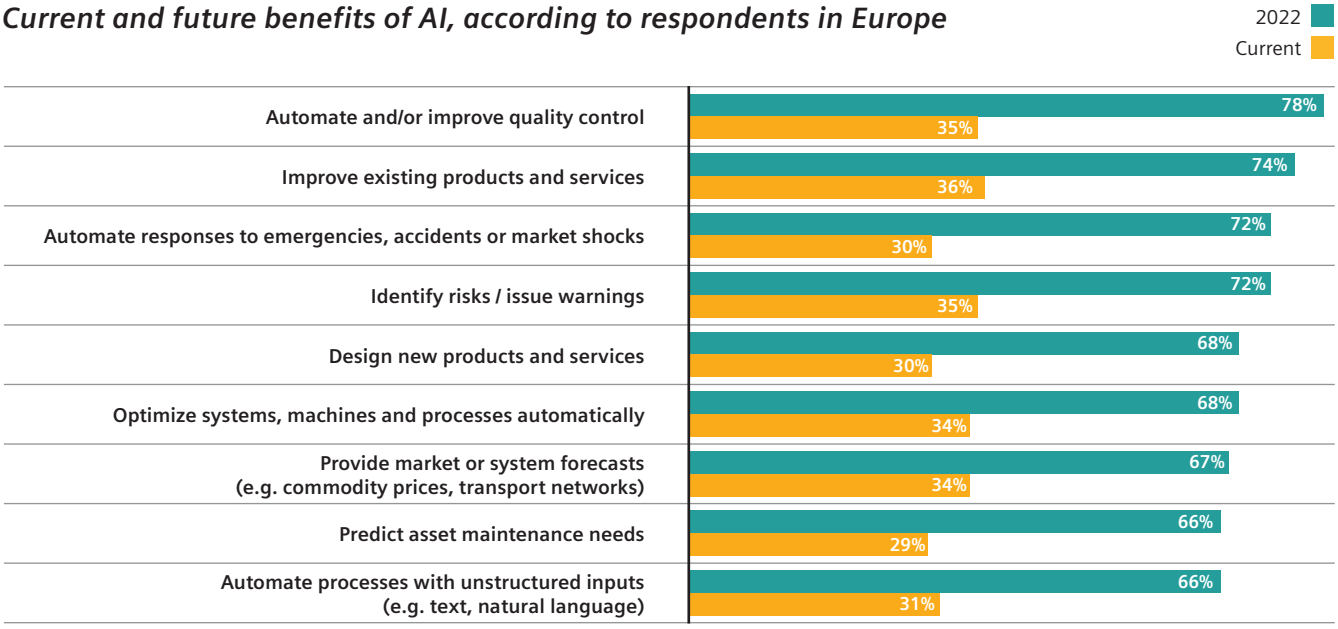
Europe respondents' conservatism here could be because they expect to make less progress in overcoming barriers to AI adoption. The most difficult of these barriers, by 2022, all relate to threats and unintended consequences: cybersecurity, liability, and safety risks.

These kinds of concerns are natural as businesses automate anything that is high value or potentially dangerous. AI allows us to automate areas that have only ever been under human control, and it has to earn our trust. However, businesses also need to make sure that progress is not blocked by unreasonable or irrational prejudices.

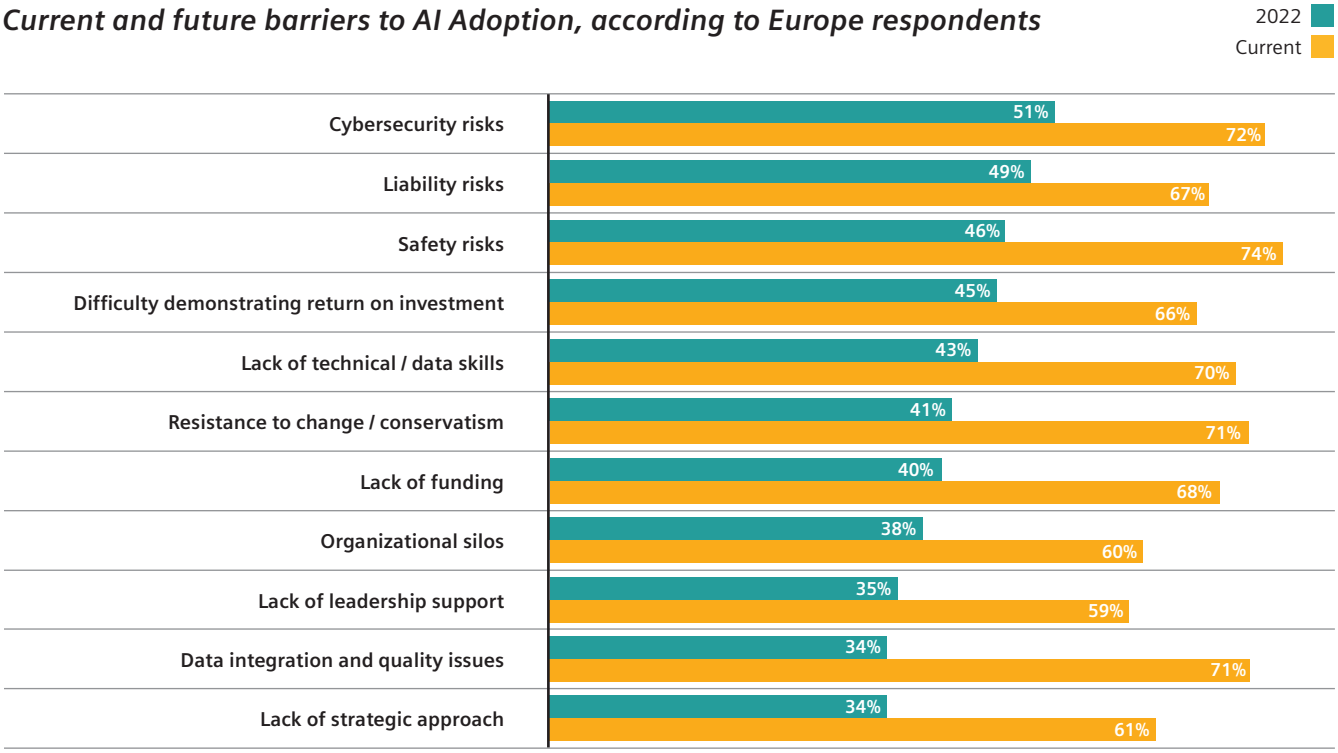
AI in a post-covid world

When this research was commissioned, there was a lot of hype around the potential of consumer AI, and fewer insights available on industrial AI. While we at Siemens, with over 30 years' experience in industrial AI, are no strangers to this field, we wanted to learn more about the experience of other organizations. This research sought to uncover the benefits and barriers of industrial AI applications, and to highlight its potential, especially when combined with other technologies like IoT and digital twin. Suddenly the world is a different place. However, as organizations seek to recover, rebuild and adapt in a post-covid environment, the potential of industrial AI is more relevant than ever.

Current and future benefits of AI, according to respondents in Europe



Current and future barriers to AI Adoption, according to Europe respondents



AI model vs. experienced employee

For example, industrial company leaders may soon be in situations where they need to decide whether to follow the recommendations of experienced colleagues or powerful AI models – they may not always agree. If leaders have a bias one way or the other, it could limit their ability to make the best choices.

To explore this kind of scenario, we asked respondents to imagine their organization has an impressive AI model – trained on 20 years of performance data – that recommends major refurbishment work on the company's machines. Doing the work would be expensive and cause significant delays. However, according to the model *not doing the work* risks a much more costly and disruptive repair.

Respondents were then asked to imagine that their head of operations – a 20-year veteran of the industry – strongly disagrees with the model, and claims that the refurbishment work would be a waste of money.

We asked Europe respondents how they would make their decision, and there is an almost even split: 51% say they would take the recommendations of the head of operations, and 49% the AI model. In other regions, there is a strong tilt toward the AI model. In Asia-Pacific, 60% go with the AI model, and it is similar in North America (41% to 59%).

Perhaps this is healthy caution from European organizations – particularly given their concerns about the risks. But it also indicates that some organizations have an aversion to change. Some might even have a specific bias against AI and automation.

What is AI?

In this report, and the research that supports it, 'artificial intelligence' and 'AI' refer to a broad spectrum of methods or technologies that perform tasks which would normally require functions of human intelligence such as learning, judging, and problem-solving. This is more in keeping with the contemporary business understanding of AI than any technical or academic conventions.

Decision time: Does AI need to outperform humans?

In another scenario, we asked respondents to consider what level of predictive accuracy, relative to a group of human employees, they would like to see from an AI model before giving it control of operational settings. The human employees were able to add value with five out of 10 of their predictions.

You can make a strong argument for the case that we should switch to the AI model at equivalent performance (i.e. five out of 10), because this saves the time and effort of the human employees, who could be directed to other tasks[1]. The more outperformance respondents want from the AI model (six out of 10 or higher), the more likely it is that other factors, such as biases and emotions, are involved.

In our overall results, for all regions, just 10% of respondents are willing to hand over control when the AI model exactly matched the human employees. Most respondents (48%) want to see the AI model do just a little better than the humans and add value in six out of 10 predictions. The remaining 42% want even greater outperformance.

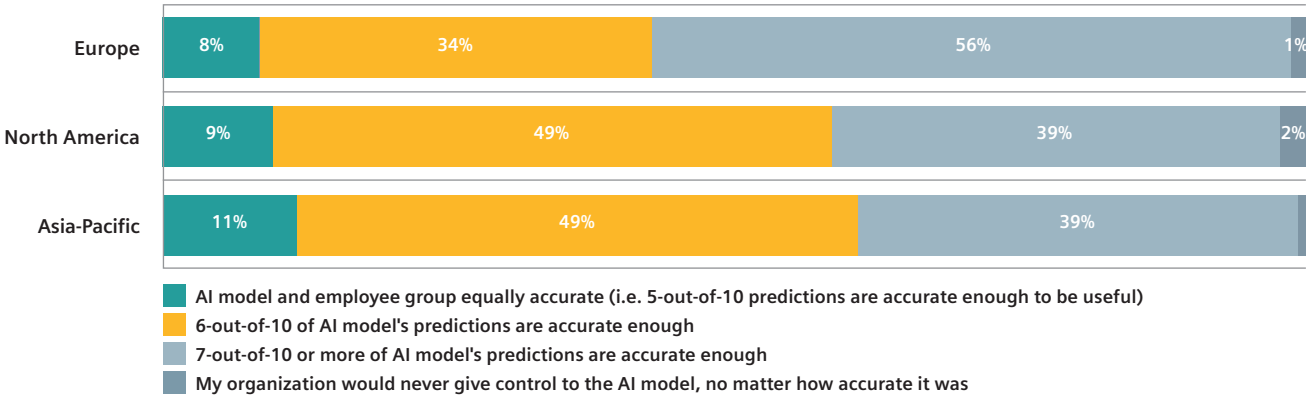
Again, Europe respondents are more reluctant than those in other regions to give up human involvement. Just 8% are happy with equal performance, 34% think that six out of 10 is sufficient, and 57% want greater outperformance.

In Europe, caution could block benefits

This reluctance suggests that Europe respondents are in general less open to AI-driven automation than those in other regions. This creates an interesting tension: all organizations need to find a balance between rushing recklessly into unknown territory and letting unreasonable caution erode competitiveness.

In Europe, our research suggests the risk is more of the latter than the former, and so industrial organizations should be sure that any limitations on the use of AI are made based on strong, evidence-based reasons.

How much accuracy do respondents need from AI before they give it control?



ABOUT THE RESEARCH: Siemens and our research partner Longitude conducted primary research[2] into the uses of, attitudes to, and outlooks for AI in industrial organizations. We surveyed 515 senior business leaders in the energy, industrial/manufacturing, urban infrastructure, and transportation sectors. The research included respondents from North America, Latin America, Europe, the Middle East and Africa, and Asia-Pacific and was concluded in September 2019. All respondents were from organizations with an annual revenue of at least $100 million. In order to qualify for the survey, respondents needed to be responsible for, involved in, or knowledgeable about their organization's existing or planned use of AI and related technologies, strategies, budgets, and applications.

[1] For simplicity, this scenario ignores capital costs needed to create the model. Instead, the question assumes the investment is sunk before our scenario begins. Operating costs of the model are assumed to be lower than the ongoing time spent by the employee group, though this was not explicit in the survey question.

Next-Gen Industrial AI

Regional Spotlight: Asia-Pacific

siemens.com/innovation

Next-Gen Industrial AI: Leading with a New Edge

The Asia-Pacific region is home to some of the world's largest and most advanced industrial complexes and infrastructure networks. The combination of economical labor pools and the world's most efficient supply chains allows the region to offer world-leading scale and value across dozens of verticals in manufacturing, heavy industry, energy, infrastructure, and transport.

However, as the next generation of industrial AI matures, other regions will have new ways to compete with the region's industries. In fact, more intelligent automation, coupled with rising labor costs in Asia-Pacific, could allow industrial competitors in Europe and North America to move their value chains from east to west.

To investigate that shift to next generation industrial AI, we conducted a survey of 515 senior leaders. Each respondent needed to be responsible for, involved in, or knowledgeable about their organization's existing or planned use of AI. Here, we discuss some of the findings from the 124 respondents in Asia-Pacific; the overall findings have been published in our Next-Gen Industrial AI report.

Organizations expect a leap forward in AI benefits

Over the next three years, Asia-Pacific respondents are expecting a significant increase in the benefits they will see from AI. More than eight in 10 expect that by 2022 they will benefit from using AI to automate quality control; to improve existing products; to optimize systems automatically; and provide market or system forecasts. All of these are expected to benefit roughly twice as many organizations by 2022 than today.

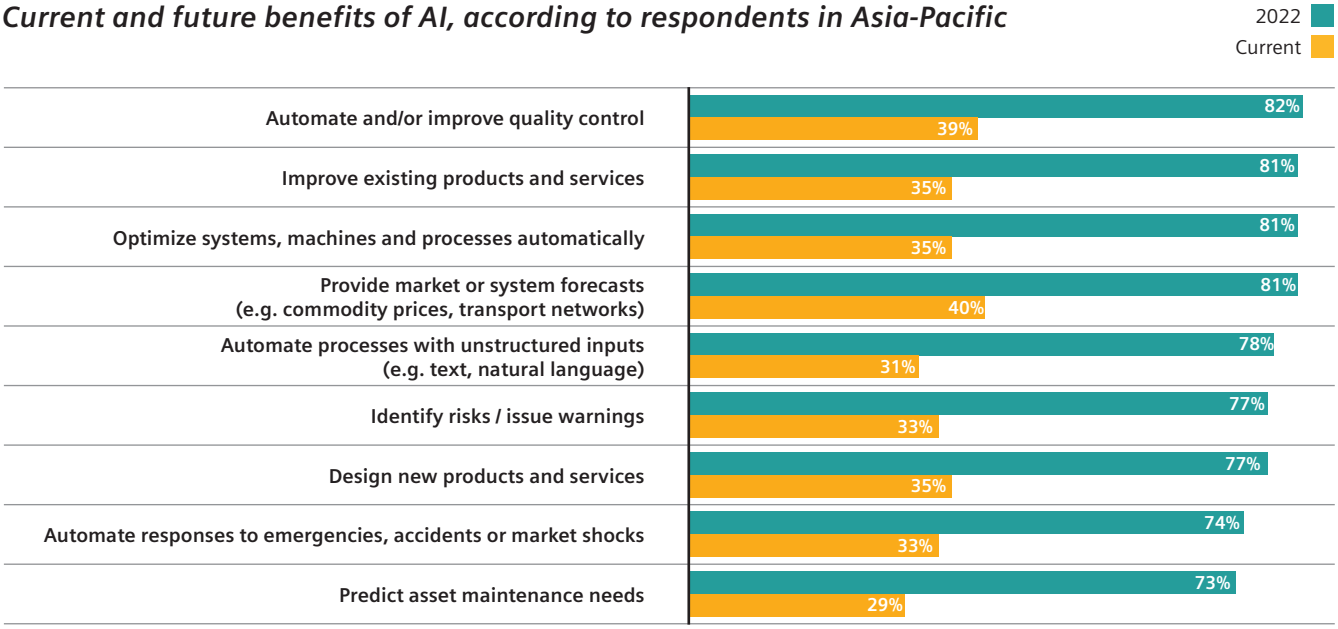
More Asia-Pacific respondents are expecting to benefit from AI by 2022 than respondents in other regions.

One explanation for this could be the attitude of Asia-Pacific respondents to obstacles to AI, many of which they are expecting to overcome. For example, their top barrier today is a lack of a strategic approach to AI, which is cited by 75% of respondents. This will fall by more than half by 2022, to 31%. Resistance to change, which is a barrier for 72% today, will fall more than any other barrier, to 28%.

AI in a post-covid world

When this research was commissioned, there was a lot of hype around the potential of consumer AI, and fewer insights available on industrial AI. While we at Siemens, with over 30 years' experience in industrial AI, are no strangers to this field, we wanted to learn more about the experience of other organizations. This research sought to uncover the benefits and barriers of industrial AI applications, and to highlight its potential, especially when combined with other technologies like IoT and digital twin. Suddenly the world is a different place. However, as organizations seek to recover, rebuild and adapt in a post-covid environment, the potential of industrial AI is more relevant than ever.

Current and future benefits of AI, according to respondents in Asia-Pacific



Respondents are expecting safety risks and cybersecurity risks to fall the least, and these are predicted to become the most prevalent barriers in three years – leap-frogging the more organizational barriers that lead today.

What does this reveal about how AI is likely to unfold in Asia-Pacific? One important point is that organizations will be invited to put ever more trust in AI. Already, there are use cases where AI-driven automation controls valuable assets and potentially hazardous machines, vehicles, and infrastructure.

As this shift in control becomes more commonplace, Asia-Pacific industry leaders will grapple with new challenges, such as when to put AI control ahead of human control, how to convince teams to put their trust in AI and how to ensure the right levels of governance are in place to control risk while allowing innovation in industrial AI to flourish.

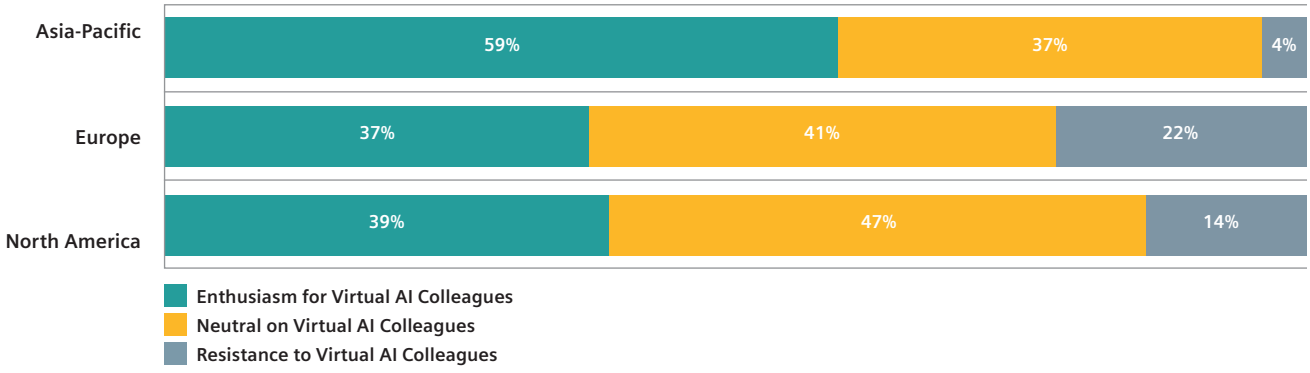
New colleagues: AI in the workforce

Compared with North America and Europe, Asia-Pacific respondents report greater openness to adopting industrial AI.

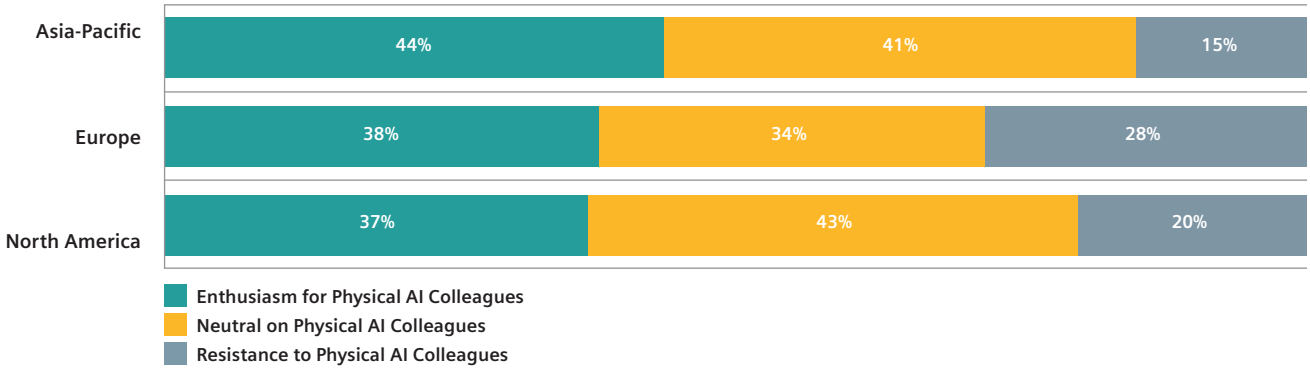
For example, we asked respondents to imagine that in the coming years AI systems begin to function much more like human colleagues, making independent decisions and acting autonomously. We described how we could classify these new colleagues as virtual AI colleagues (e.g. AI assistants, analysts, market traders) or physical AI colleagues (e.g. robots, vehicles, machines). We then asked respondents what they thought their workforce's attitude – from strong enthusiasm to strong resistance – would be to adopting these two kinds of autonomous AI colleagues.

For both virtual and physical AI colleagues, Asia-Pacific respondents are much more likely than either North American or European respondents to say their organization would be enthusiastic. And on the flipside, just 4% of Asia-Pacific respondents say they would expect resistance to virtual AI colleagues, while more than three times as many expect resistance in North America (14%), and more than five times as many in Europe (22%).

Attitudes towards working with virtual AI colleagues



Attitudes towards working with physical AI colleagues



Asia-Pacific appears one step ahead

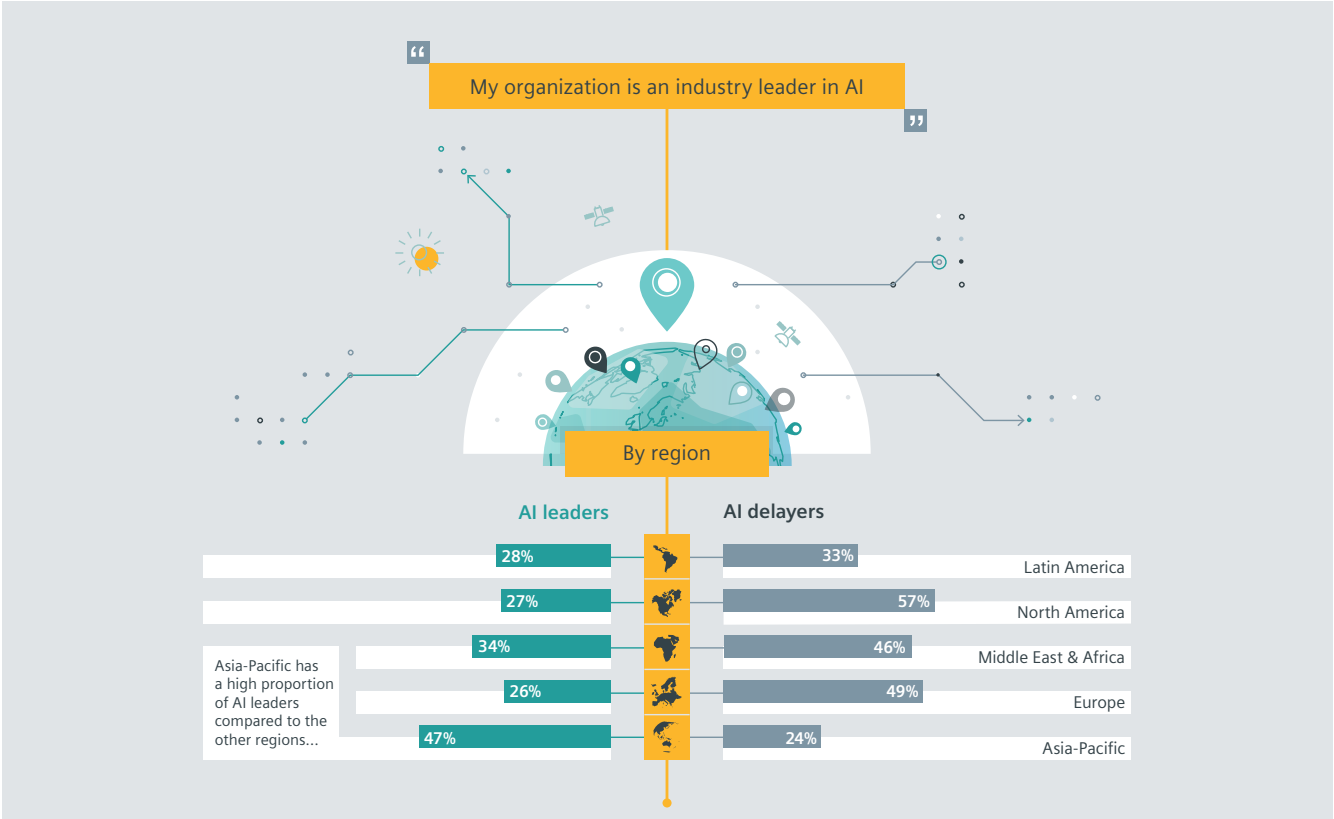
Asia-Pacific respondents in our research suggest that the region is already ahead in industrial AI, with 61% saying it has already had a significant positive impact on their organization, compared with 51% in Europe and 43% in North America.

And nearly twice as many (47%) report that their organization is an industry leader in the use of AI, compared with just 26% in Europe and 27% in North America. If organizations in the region build on that advantage, it could help them to offset competitive pressure from rising wages, regulatory change, and economic turmoil.

Many in North America and Europe see the potential of industrial AI applications to transform their global competitiveness, but they are not moving fast enough to make it a reality. Industrial powerhouses in Asia-Pacific, on the other hand, are racing ahead, replacing one advantage with another in the battle to maintain their edge.

What is AI?

In this report, and the research that supports it, 'artificial intelligence' and 'AI' refer to a broad spectrum of methods or technologies that perform tasks which would normally require functions of human intelligence such as learning, judging, and problem-solving. This is more in keeping with the contemporary business understanding of AI than any technical or academic conventions.



ABOUT THE RESEARCH: Siemens and our research partner Longitude conducted primary research[1] into the uses of, attitudes to, and outlooks for AI in industrial organizations. We surveyed 515 senior business leaders in the energy, industrial/manufacturing, urban infrastructure, and transportation sectors. The research included respondents from North America, Latin America, Europe, the Middle East and Africa, and Asia-Pacific. All respondents were from organizations with an annual revenue of at least $100 million. In order to qualify for the survey, respondents needed to be responsible for, involved in, or knowledgeable about their organization's existing or planned use of AI and related technologies, strategies, budgets, and applications. The research included respondents from North America, Latin America, Europe, the Middle East and Africa, and Asia-Pacific and was concluded in September 2019.

Next-Gen Industrial AI

Regional Spotlight: North America

siemens.com/innovation

Next-Gen Industrial AI: The New Frontier for Global Competitiveness

The industrial sectors in the United States and Canada have battled through decades of outsourcing, market shocks, regulatory changes, and economic policy shifts.

As we enter the 2020s, both countries are looking for ways to drive both reshoring and new industrial growth. Ways to support this include boosting skilled labor, cheap energy, and low-carbon production methods. However, it seems certain that innovation and proficiency with new technologies will be crucial to competitiveness, and one area with real transformative potential is the next generation of industrial AI.

To investigate the shift toward the next generation of industrial AI, we conducted a survey of 515 senior leaders. Each respondent needed to be responsible for, involved in, or knowledgeable about their organization's existing or planned use of AI. Here, we discuss some of the findings from the 122 respondents in the United States and Canada (hereafter North America); the overall findings have been published in our Next-Gen Industrial AI report.

Three times the benefits by 2022?

A minority of North America respondents are currently benefiting from industrial AI applications, but about three times as many expect to benefit in just three years' time. The top expected benefits by 2022 include using AI to automate quality control; identify risks; and optimize systems automatically.

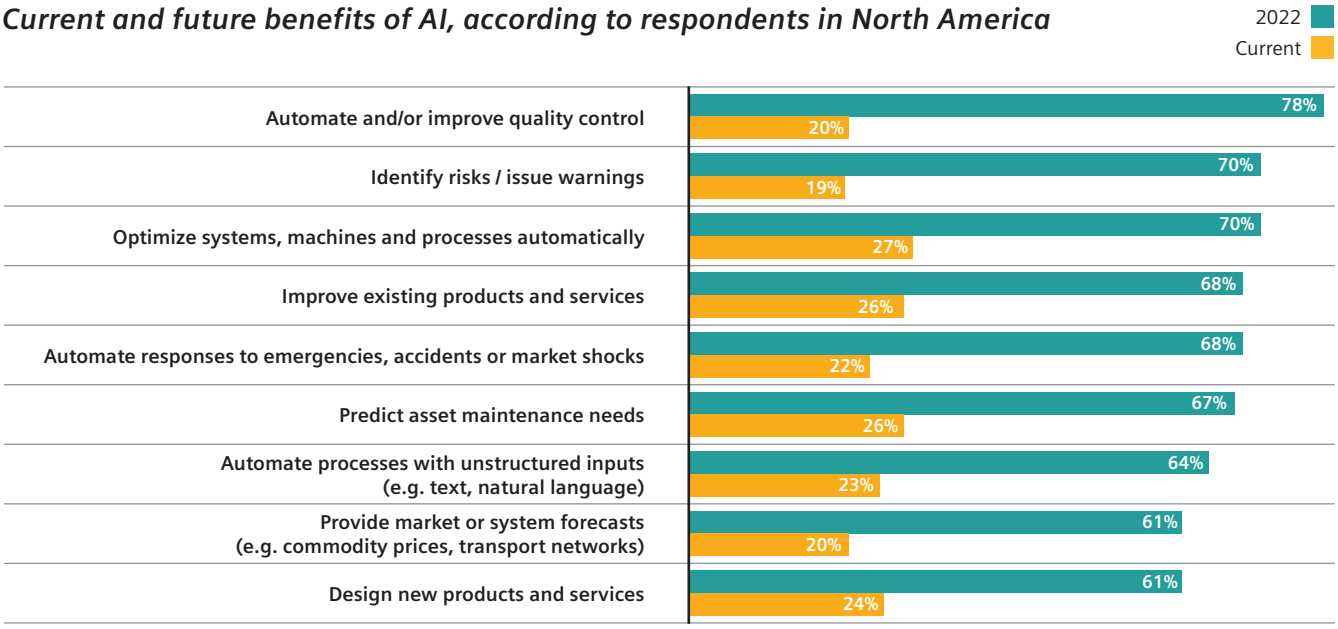
This is a rapid rise in benefits, but it is also expected in other regions – and North America is starting from a lower base: it is behind Europe and Asia-Pacific in terms of the current benefits.

The reason for this could be the prominence of certain key barriers to progress with AI, and especially the top barrier for North America respondents: reluctance to change/ conservatism. At present, 83% of North America respondents say that this barrier has a moderate or major negative impact on their progress with AI, which is significantly more than Europe (71%) and Asia-Pacific (72%).

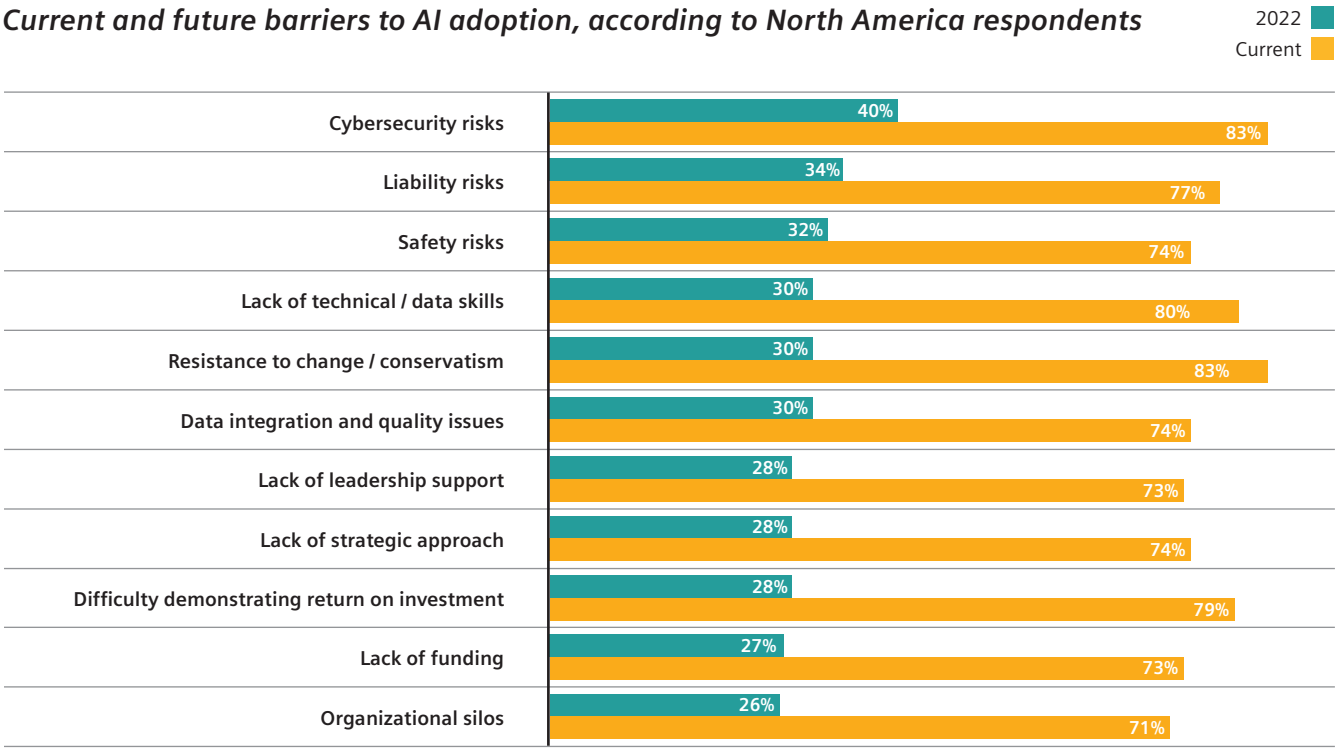
AI in a post-covid world

When this research was commissioned, there was a lot of hype around the potential of consumer AI, and fewer insights available on industrial AI. While we at Siemens, with over 30 years' experience in industrial AI, are no strangers to this field, we wanted to learn more about the experience of other organizations. This research sought to uncover the benefits and barriers of industrial AI applications, and to highlight its potential, especially when combined with other technologies like IoT and digital twin. Suddenly the world is a different place. However, as organizations seek to recover, rebuild and adapt in a post-covid environment, the potential of industrial AI is more relevant than ever.

Current and future benefits of AI, according to respondents in North America



Current and future barriers to AI adoption, according to North America respondents



The race for a new advantage

So, what kind of impacts could this reluctance to change, and other high barriers, have on US industrial organizations? Without some effort to catch-up, it could dent long-term global competitiveness. Asia-Pacific is home to some of North America's biggest industrial sector rivals. It is also the leading region across a range of measures in our survey, which makes it a useful benchmark to contrast with the North America results.

And those contrasts can be stark. For instance, just 27% of North America respondents say that their organization is an industry leader in the use of AI, compared with 47% of Asia-Pacific respondents. This reflects an advantage that appears to have produced real results, with 61% of Asia-Pacific respondents saying that AI has already had a significant positive impact on their organization, compared with just 43% of North America respondents.

Some 69% of Asia-Pacific respondents, meanwhile, say their organization is keen to use as much AI as possible, compared with 53% of North America respondents. This means that without some significant move by industrial organizations in North America to gain ground, their counterparts across the Pacific look likely to maintain or increase their edge.

What is AI?

In this report, and the research that supports it, 'artificial intelligence' and 'AI' refer to a broad spectrum of methods or technologies that perform tasks which would normally require functions of human intelligence such as learning, judging, and problem-solving. This is more in keeping with the contemporary business understanding of AI than any technical or academic conventions.

Confidence in theory more than practice

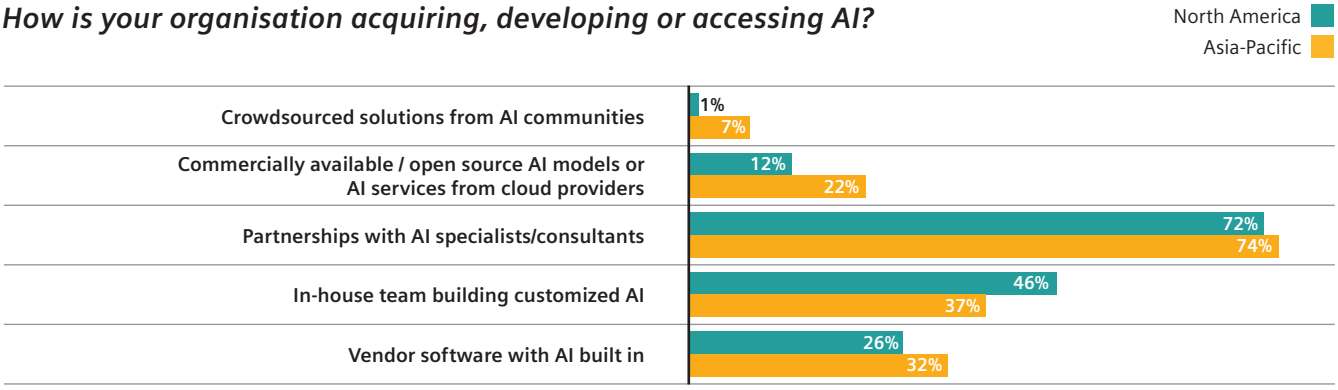
The survey contained a number of questions that asked respondents to consider hypothetical scenarios related to AI in their organizations. It is interesting to note that in their responses to these questions North American respondents did not have the same reticence as Europe respondents toward trusting AI-driven predictions or automation. In fact, they were similar to Asia-Pacific respondents, both in the performance they would require from an AI model, and in favoring the decision of an impressive AI model over an experienced human colleague.

At the same time, just 39% of North America respondents think that within five years some of their organization's high-value assets will be under autonomous AI-control, compared with 60% for Asia-Pacific (and 55% for Europe). So, while they share similar levels of confidence in AI models, North America respondents expect much less automation of important assets than their Asia-Pacific counterparts.

We have seen how several key barriers to progress are prevalent in North America – to a greater extent than in Asia-Pacific – and this may explain that difference. But it is also important to consider the different strategies used by organizations to access the benefits of Industrial AI.

North America respondents are mostly using partnerships with AI specialists and in-house teams to acquire, develop, or access AI. By contrast, fewer Asia-Pacific respondents report using an in-house team, but more are using off-the-shelf options, vendor software with built-in AI, and crowdsourced AI solutions. Greater use of those approaches could be one way North American organizations could speed up AI-driven improvements and keep pace with rivals around the world.

How is your organisation acquiring, developing or accessing AI?



ABOUT THE RESEARCH: Siemens and our research partner Longitude conducted primary research[1] into the uses of, attitudes to, and outlooks for AI in industrial organizations. We surveyed 515 senior business leaders in the energy, industrial/manufacturing, urban infrastructure, and transportation sectors. The research included respondents from North America, Latin America, Europe, the Middle East and Africa, and Asia-Pacific. All respondents were from organizations with an annual revenue of at least $100 million. In order to qualify for the survey, respondents needed to be responsible for, involved in, or knowledgeable about their organization's existing or planned use of AI and related technologies, strategies, budgets, and applications. The research included respondents from North America, Latin America, Europe, the Middle East and Africa, and Asia-Pacific and was concluded in September 2019.

Published by
Siemens AG in cooperation
with Longitude Research Ltd

Werner-von-Siemens-Str. 1
80333 Munich,
Germany

www.siemens.com/innovation

Thank you to all contributors
for their time and insights!