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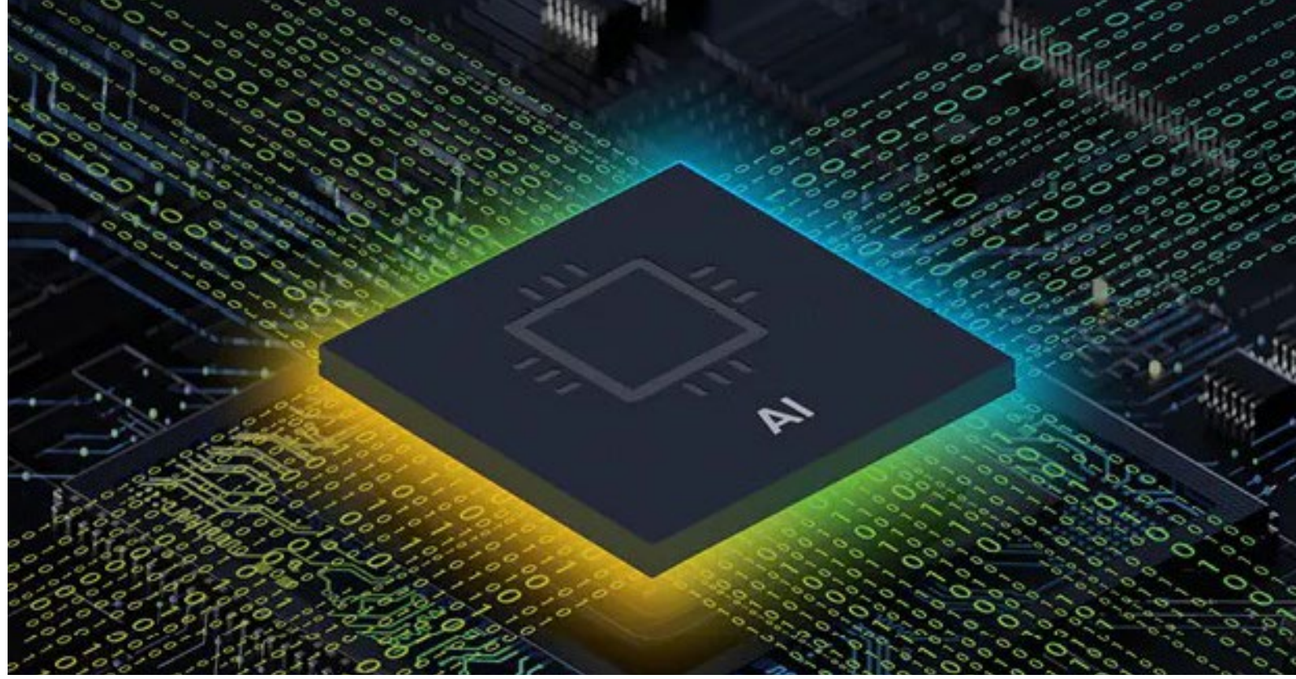

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ADVANCED CNC MACHINING – CURRENT SCENARIO AND EMERGING TRENDS

Advanced CNC machining will become a critical pillar of smart manufacturing, enabling flexibility, efficiency, and precision, says Milton D'Silva.

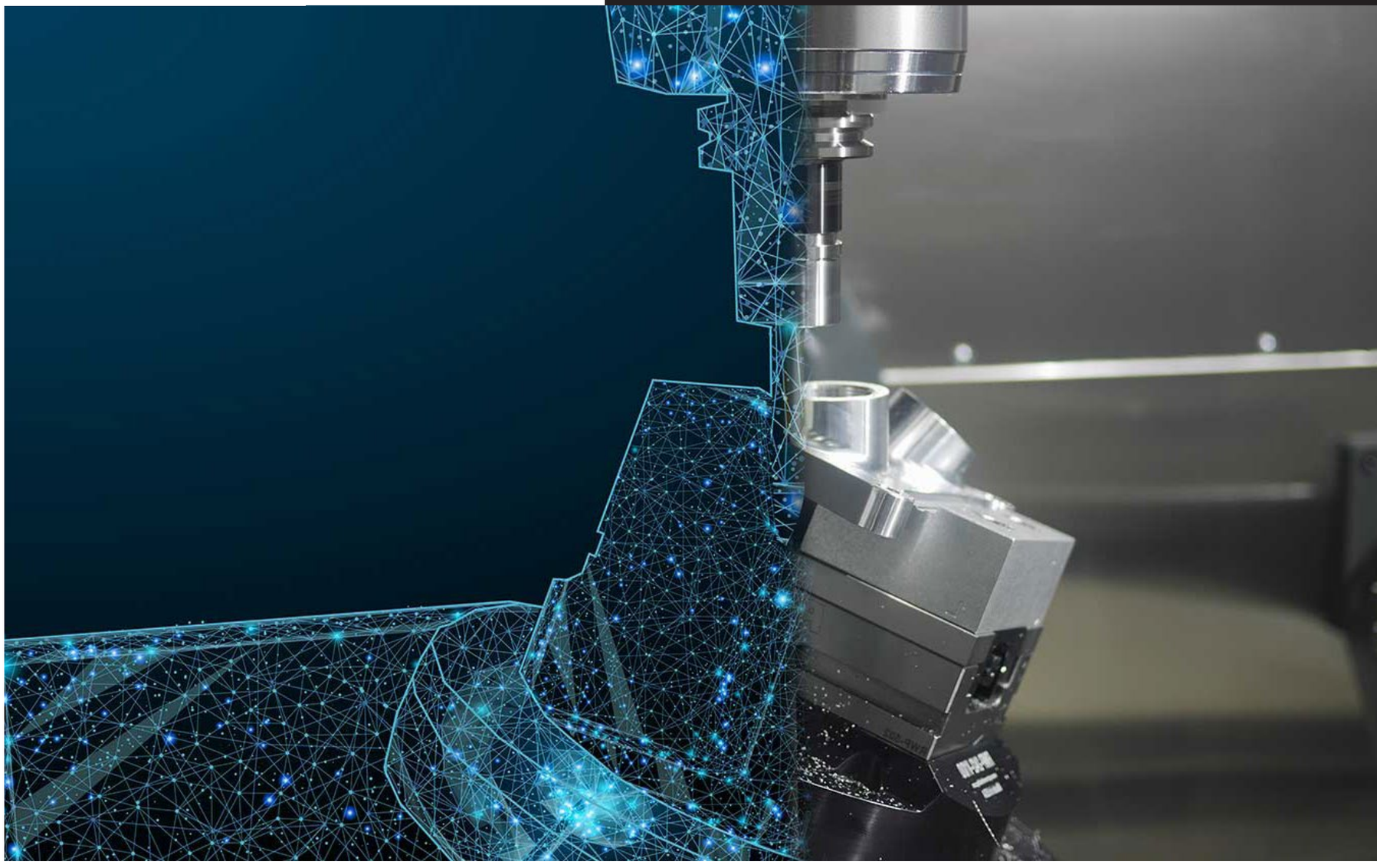
Machine tools are used to shape, cut, or finish parts made of metal or other materials. They are essential for producing a wide range of components, from consumer goods to automobiles, aircraft and spacecraft and parts for other machines. Machine tools form the core part of the manufacturing process of the products in daily use.

Machine tools have evolved over several millennia with records suggesting use of bow drills to make holes in wood and stones by ancient Egyptians, Greeks and Romans in the BC era. These civilisations had also developed the early lathe, operated by two persons, where one person turned the wooden work pieces while the other worked on it with a sharp tool. Such lathes were used to make a variety of objects like containers and furniture parts. Later more advanced tools like water mills and hydraulic presses evolved. All these tools were mostly manually operated, though later horse drawn boring machines were used to fabricate canons. Rapid advances in machining operations were made during the Industrial Revolution that began in the late 18th century with the invention of the steam engine that led to other machines like the spinning jenny and milling machine. These tools, driven much faster by steam power boosted both power and efficiency, and thus began the era of mechanised machine tools.

The development of cast iron beds and slide rests further improved the accuracy and reliability of the machining process, making the lathe truly 'the mother of all machine tools'. Steam power was later replaced by electric motors by the late 19th and early 20th century as the lathe continued to evolve, improving both speed and precision. From here to semi-automation and further full automation was a relatively short journey, and by mid-20 century, a numerical control (NC) system was introduced with punch cards to control machining operations. The NC system was soon coupled with computers which ushered in the CNC era, with full automation of the operation, raising accuracy to a new high and bringing in complex geometries in parts manufacturing.

Incidentally, this evolution of machine tools happened in tandem with the rapid advancements in the automotive, aerospace, white goods and medical equipment industries. The high precision requirements of these industry segments for intricate parts with complex geometries called for

CNC simulation software helps manufacturers avoid errors. Image credit: Hexagon



Launch of the Mazak Integrex i-630V/6 AG multi-tasking machine at EMO 2023. Image credit: Rainer Jensen/VDW

specialised machining capabilities. This in turn pushed the boundaries of innovation in the machine tool industry, spurring mutual advancements in technology, aiding the growth of both segments. To cite just one example, the increased fuel efficiency of modern automobile engines has been largely facilitated by CNC machines that enabled the production of lighter, more efficient, and better-performing components – engine blocks, cylinder heads and differential cases – and vehicle structures. This article explores the current state and future direction of advanced CNC machining.

Current scenario of CNC machining

The contemporary scenario in CNC machining is far removed from the early days, with machines now increasingly automated, digitised, and integrated with smart manufacturing systems. Advanced CNC technologies like 5-axis machining, robotics, AI-driven process optimisation, and digital twins are becoming more common, especially in high-precision industries like aerospace, medical and automotive. However, adoption is uneven, with SMEs lagging due to cost, skill gaps, and integration challenges. The push toward Industry 4.0 and customization is accelerating demand, but widespread adoption still faces notable barriers.

The state of the industry

Necessity is the mother of invention. This well known proverb perhaps has more relevance to the machine tool sector than any other, as all important innovations like numerical control happened as a response to the demands of the industry. The 20th century is known for giant strides made in automobiles, aviation and aerospace, shipping and transport, nuclear energy, the white goods revolution and the medical equipment industry, each having its own set of demands for machining – the art of cutting metal to suit specific requirements. The machine tool industry on its part rose to these challenges admirably, literally providing the cutting edge. Compared to other industries, the digitalisation of the machine tool industry began quite early, in the 1940s with the NC system and progressed further with CNC machines. Further developments like integration of CAD/CAM, PC-based open architecture controllers, use of sophisticated software for advanced machining operations followed.

According to Fortune Business Insights, a leading market research agency that also provides end-to-end solutions beyond flagship research, the global CNC machine tool market size was valued at USD 95.29 billion in 2024. This is projected to grow from USD 101.22 billion in 2025 to USD 195.59 billion by 2032, exhibiting a CAGR of 9.9% during the forecast period. The remarkable market growth is propelled by the healthy demand for more automation and precision in the manufacturing industries. Key sectors driving demand today are automotive, electronics, aerospace & defense, power & energy, construction equipment, and medical devices. The massive infrastructure growth in developing countries as well as growing emphasis on decarbonisation of energy are the leading drivers.

Common CNC machine tools

Apart from the ubiquitous lathe that remains as popular as ever as the most basic machine for any workshop, common CNC machine tools are turning, milling and drilling machines, grinders, plasma and laser cutters, waterjet cutters, electric discharge machines (EDMs), etc. The EDM is not a traditional metal working machine, but a machining process that uses electrical sparks to remove material from a workpiece. Then there are various types of metal forming machines like CNC press brakes, hydraulic bending machines, punch presses and plate rolling machines, also in extensive use. For the record, machine tools today are broadly classified in two groups – metal cutting machines and metal forming machines. Cutting machine tools remove material from a workpiece by shearing or chipping, while forming machine tools reshape the material by bending or pressing, without cutting or removing any of it. Among the leading global manufacturers of advanced CNC machine are well known brands like DMG MORI (Germany & Japan); MAZAK (Japan); MIKRON (Switzerland); MAKINO (Japan); CHIRON (Germany); Okuma (Japan); Hermle (Germany); GROB (Germany); YASDA (Japan); Haas Automation (USA); EMAG (Germany); Doosan (Korea); Matsuura (Japan); Starrag (Switzerland); and Hurco (USA). Apart from these, there are hundreds of other manufacturers. Speaking of countries with large volumes of machine tool production, China, Taiwan, Italy, Spain, and India figure among the leading manufacturers.

Multi-axis machines

A significant aspect of modern machine tools is the development of multi-axis machines. Traditionally, CNC machines worked only in three axes – x, y and z – representing linear movements. Together, these movements – left to right (x), front to back (y), and up and down (z) – are enough for most machining applications. However, for parts with complex geometries required for aerospace and medical applications and also in modern automotive components, the 3-axis machines are inadequate and hence multi-axis machines were developed that offered additional rotational axes. Apart from the ability to produce complex shapes, multi-axis machines – 5-axis machines are today commonly used – also provide increased accuracy and faster production speeds with reduced setup times.

Another area where contemporary machine tools have achieved great success is improvement in high precision, high accuracy and repeatability, attributes that matter most in machining parts with sub micron tolerances for demanding applications in aerospace and other industries. This is also aided in no small measure by the integration of CAM software and simulation tools, as well as advanced measuring instruments like Coordinate Measuring Machines (CMMs), laser scanners, and digital micrometers.

Operational improvements

Unattended machining today is no longer a fantasy with robotic loaders, bar feeders, and tool changers allowing 24/7 machine operation. At the moment though there are human supervisors overseeing operations in such

A visitor checking a latest CNC machine model at TIMTOS exhibition, Taiwan. Image credit: TAITRA.

AI generated image of a CNC machine producing a component with intricate design. Image by Freepik

automated workshops, lights-out machining is a reality at many manufacturers, the most notable example being FANUC, the company operating its own factory on the lights-out model since 2001. Several other leading machine tool manufacturers are also known to operate their third shift – the most unpopular among human workers – as light-out shift.

The other improvements are IoT-enabled monitoring where sensors capture data like spindle loads, vibrations, and tool wear. Platforms like MTConnect and OPC-UA help standardise data for analytics. With automated inspection, on-machine probing and in-process metrology reduce scrap and ensure dimensional accuracy.

Emerging trends in advanced CNC machining
With advanced CNC machining the following trends are now emerging in the manufacturing space:

Integration of Smart Manufacturing & Industry 4.0
With the advent of Industry 4.0 and the concept of connected machines, CNC machine tools have now progressed into the advanced automation era. Connected machines or Cyber-Physical Machine Tools (CPMT). These machines, equipped with sensors, embedded computers, and network connectivity, integrate computation with physical processes, allowing monitoring, control, and even autonomous operation of CNC machines. Two or more machines now combine to form cells for specific purposes like production of alloy wheels for cars, the machines tended by robots and monitored by AI to oversee seamless integration with automated inspection equipment and image processing technologies. These machines now move effortlessly from mass manufacturing to mass customisation for a hypothetical production run of a single part, one of the basic attributes of the Industry 4.0 ecosystem of smart production.

Predictive Maintenance
One of the significant advantages connected CNC machines bring to the table is enabling predictive maintenance using machine learning by algorithms. The data gathered by sensors of various parameters – temperature, vibration and power consumption – can yield valuable insights on the actual running condition of machines. This is assisted in no small measure by the use of digital twins and simulation. These virtual replicas of physical assets allow real-time monitoring, data analysis, and simulation of various scenarios to predict potential failures and optimise maintenance strategies. This enables proactive maintenance, reduces downtime, and improves asset performance. By addressing issues early, the cost of repairs and component replacements is reduced. Predictive maintenance also ensures machines operate at peak performance for longer periods.

Hybrid Machining – Additive + Subtractive
Perhaps the most interesting trend now emerging in CNC machining is the combination of additive and subtractive technologies into hybrid manufacturing. While traditional machining is subtractive – removing metal from a solid block to get the desired shape, additive manufacturing actually deposits layers of substrates to form a component. The additive + subtractive hybrid machining (ASHM) is ideal to create parts with complex geometries and high precision used in aviation and medical industries. The process overcomes the limitations of each individual method by utilising the advantages of both. For example, a 3D printed

DMG MORI and Siemens presented the first end-to-end digital twin for machine tool machining on Siemens Xcelerator. Image credit: Siemens

part can be subsequently machined to improve surface finish, dimensional accuracy, or to create internal features that are not easily achievable through additive manufacturing alone. More importantly, ASHM can minimise material waste compared to traditional manufacturing techniques. In some cases, it can lead to faster production times by leveraging the rapid prototyping capabilities of additive manufacturing and the precision of subtractive processes.

Artificial Intelligence and Machine Learning Applications

Among emerging technologies, Artificial Intelligence and Machine Learning (AI & ML) are the real game changers. Besides helping in predictive maintenance, AI & ML are instrumental in optimising automated toolpaths with real-time parameter adjustments. AI can analyse vast amounts of data to identify patterns and trends, providing data-driven insights for process optimisation. While AI helps automate post-cutting quality inspections to ensure dimensional accuracy and surface finish faster than what is humanly possible, ML algorithms can be trained on historical data to improve the accuracy of CNC machining processes. Besides, AI-powered CNC systems can adapt to new designs and materials with minimal human intervention, making them more flexible and adaptable to changing production needs. AI optimises workflows by analysing data and adjusting machine parameters in real-time, leading to faster production cycles and reduced errors. ML helps by analysing the datasets and then saving for future references, eliminating the need to repeat the process for every cycle, every time. Together, these technologies enhance CNC processes by learning from vast datasets, enabling more dynamic and adaptive workflows, and ultimately reducing waste, production time, and operational costs.

Advanced Materials and Tooling

It is not just technologies that are ushering in revolutionary changes in CNC machining. Advanced materials and tooling are also playing an important role in this revolution by facilitating the production of more complex and precise parts, while also improving efficiency and reducing costs. It is now possible to use high-strength steel and aluminium alloys, and hard-to-machine metals like titanium alloys thanks to a combination of high speed and high precision machining in combination with advanced cutting tools with high performance coatings. Tools made of carbide or ceramic, and coated with various materials like titanium nitride (TiN), titanium carbonitride (TiCN), aluminum titanium nitride (AlTiN), and diamond-like carbon (DLC), are ideal for high speed machining. These tools not only offer superior wear resistance and heat tolerance, but also

extended tool life and improved machining efficiency. Besides, the development of new cutting tool geometries and materials allows for faster machining speeds and more complex part geometries. Further, emerging technologies like sensor-equipped tools enable real-time monitoring of tool performance, allowing for predictive maintenance and optimised machining parameters. All these innovations are driving precision, accuracy, and scalability in various industries, including aerospace, automotive, bio-medical and beyond. Also used now are various composites like carbon fibre reinforced polymers (CFRP) which are lightweight, with high strength and durability, making them ideal for aerospace and automotive applications.

Human-Machine Collaboration and Skills Evolution

Amidst the evolution of technology, there is the constant and all important human element for which there is no substitute. Technology is after all produced by human intelligence and efforts, a constant endeavour to make things better. The human-machine collaboration allows for a more integrated approach, where human expertise and machine capabilities are combined to optimise the machining process, ultimately leading to improved productivity and product quality. By leveraging human expertise and machine automation, the collaboration between humans and machines optimises the machining process, leading to increased productivity and higher output. The synergy between human creativity and machine capabilities fosters innovation and problem-solving in the machining process, leading to the development of new techniques and approaches. As humans and machines collaborate, the skills of machine operators evolve to include a deeper understanding of machine capabilities, data analysis, and programming, allowing them to work more effectively with the advanced technology.

Entry barriers and challenges

With all the advantages highlighted above, advanced CNC machining – technologies like 5-axis machining, multi-tasking machines, automation, and digital twins – ought to be widely adopted globally in quest of better quality and high efficiency of every product manufactured. However, in reality, this is easier said than done. Their widespread adoption faces several entry barriers and challenges despite the potential to revolutionise manufacturing. What exactly are these challenges is briefly examined point by point in the following paragraphs.

1. High Capital Investment – the very first obstacle faced in any new technology adoption globally is the cost, which obviously is high initially. Advanced CNC machines and associated automation (robots, sensors, AI software) are expensive and the return on investment is the first thing that presents itself as a barrier. While large corporations may not face this problem, many small- and medium-sized enterprises (SMEs) that are significant players contributing to manufacturing output, struggle to justify or secure funding for the initial investment.

2. Skills Shortage – A lack of qualified personnel who can program, operate, and maintain advanced CNC systems. This is more so given the penchant of young engineers today to prefer the services industry with better earnings than the manufacturing sector. As a result, the workforce often lacks training in areas like CAD/CAM integration, G-code customisation, 5-axis kinematics, and system diagnostics.

3. Complexity of Technology, Long Learning Curve – Integrating CNC machines with ERP systems, IoT platforms, and AI-driven analytics requires significant expertise and customisation, as well as new workflows and process re-engineering. The main challenges manufacturers face are difficulties with data standardisation, real-time connectivity, and cybersecurity. The inherent tendency of the workforce to resist change adds to the fear of obsolescence.

4. Limited Interoperability and Vendor Lock-In – A serious concern shared by many entrepreneurs is the complexities that arise from having machines from different manufacturers and their proprietary software and interfaces. This limits flexibility and increases long-term costs due to dependence on specific vendors for upgrades and maintenance. Add to that the supply chain and tooling dependencies, and the problem of spare parts that may not be locally available, adding to delays in implementation or increased OPEX.

5. Maintenance and Downtime Risks – Advanced machines have more components and sensors, increasing the risk of technical failures if not properly maintained. This again relates to the lack of adequate skills mentioned earlier. The challenge is the unplanned downtime can be costly and impact production schedules severely.

6. Data management and system integration complexities – CNC machining involves complex interactions between hardware, software, and data systems. Integrating machine data with MES, ERP, or PLM systems is difficult without standardised protocols. Inconsistent formats for toolpath data, machine logs, or maintenance reports create compatibility issues.

7. Regulatory and Compliance Issues – In sectors like aerospace or medical devices, any change in manufacturing technology must be validated and certified. The time and cost of re-certification can deter innovation apart from delaying project execution, adding to costs.

8. Cybersecurity Concerns – The elephant in the connected ecosystem room today is cybersecurity. CNC systems integrated with the cloud or IoT are vulnerable to cyberattacks. The challenge here is to be a step ahead of hackers and cybercriminals. Ensuring secure data transfer, remote monitoring, and protection against malware/ransomware is an ongoing concern.

Future Outlook

Given the rapid pace of evolution of breakthrough technologies, what is the future outlook for the machine tools industry in general, and advanced CNC machining in particular, in the world of manufacturing?

The future of advanced CNC machining not only looks promising, but with its role expanding significantly as part of the broader Industry 4.0 transformation, it is also going to play a significant role in the emerging sustainable

MARKET OVERVIEW

manufacturing ecosystem. The following are the key trends shaping this outlook:

1. Cryogenic machining and minimum quantity lubrication (MQL) – Cryogenic machining uses extremely cold liquefied gases, like liquid nitrogen or carbon dioxide, as a coolant during machining to reduce heat and improve tool life. Minimum quantity lubrication (MQL) uses a small amount of lubricant, often atomised and delivered with compressed air, to reduce heat and improve lubrication in the cutting zone. Benefits include increased tool life, especially in hard materials, higher material removal rates. Also uses a minimal amount of lubricant, often delivered as an aerosol with compressed air, to lubricate the cutting tool and workpiece. This approach can improve lubrication and cooling capabilities, potentially leading to better machining performance, especially for difficult-to-cut materials.

2. Greater Automation and Autonomy – Already at the peak of advanced automation, CNC machines will become increasingly self-optimising and autonomous, integrating AI for real-time process adjustments, error correction, and adaptive toolpaths. The age of next generation AI-native, self-learning machines is not too distant now.

3. Full Digital Integration – In line with the emerging industrial metaverse, seamless integration with digital twins, IoT platforms, and smart factory systems will become the norm in the world of CNC machining. This will in turn further fine-tune the already prevailing trends of predictive maintenance, remote monitoring, and simulation-driven machining.

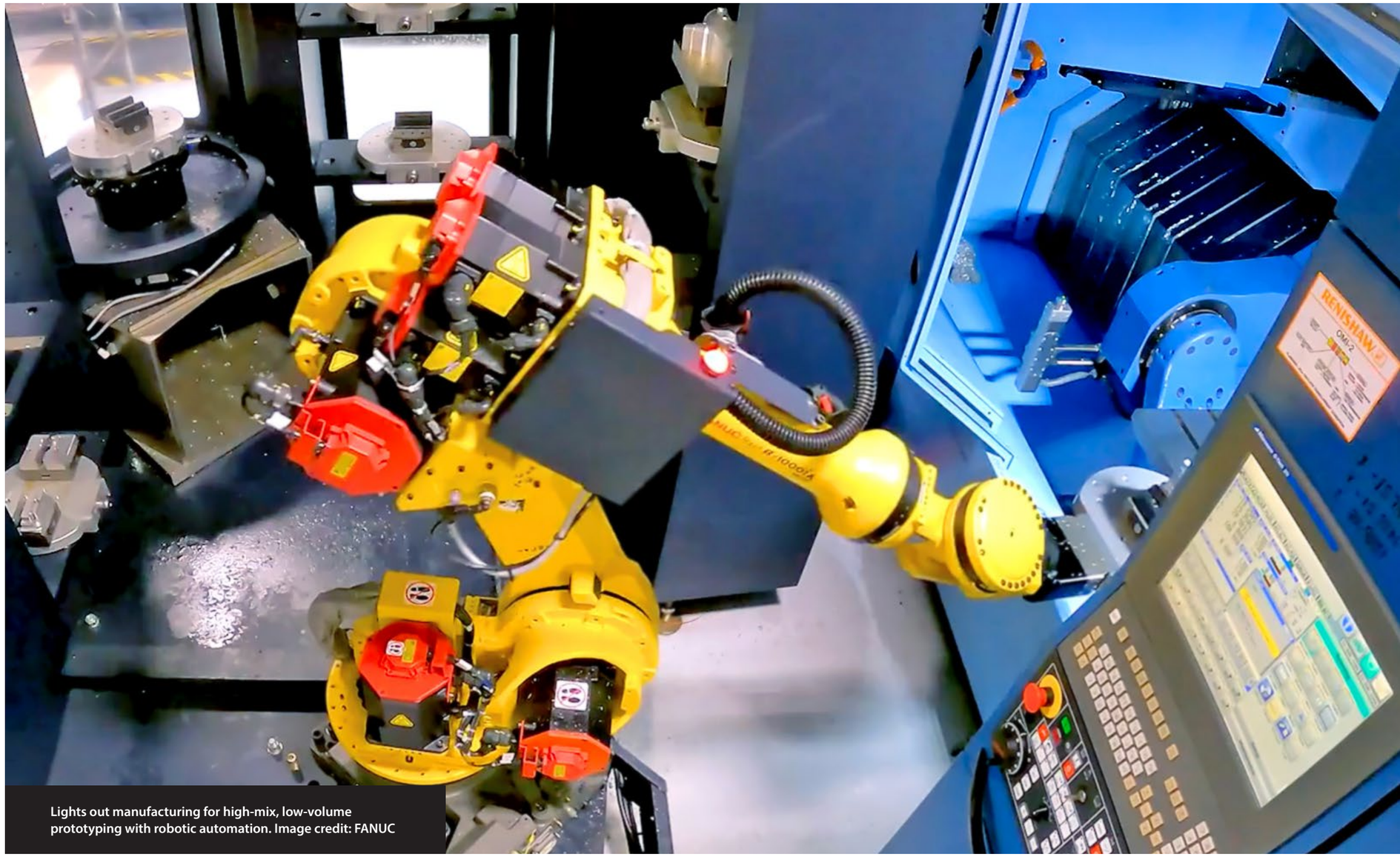
4. Customisation and Agile Manufacturing – CNC machines will play a central role in low-volume, high-mix production to meet the demand for personalised products and rapid design-to-part cycles. The future is in moving beyond mass production to the era of mass customisation.

5. Widespread Use of Advanced Materials – In the quest of energy efficiency and decarbonisation, CNC machines will increasingly handle composites, ceramics, and exotic alloys, driving innovation in aerospace, medical, and automotive sectors.

6. Democratisation via Cloud and AI – Cloud-based CAD/CAM software and AI-assisted programming will lower entry barriers for smaller manufacturers, making high-precision machining more accessible. This will also be supplemented by Machining as a Service (MaaS) – a cloud-based, on-demand manufacturing model where customers outsource their CNC machining needs to a network of service providers, rather than investing in their own machines or facilities.

7. Sustainability and Energy Efficiency – Future CNC systems will focus on energy-efficient operations, minimal waste, and circular economy principles, aligning with green manufacturing goals.

8. Collaborative Robotics (Cobots) – With the increasing role of cobots in machine tending and related applications, human-machine collaboration in CNC environments will increase, enhancing productivity and safety, particularly in hybrid manufacturing setups.



Lights out manufacturing for high-mix, low-volume prototyping with robotic automation. Image credit: FANUC

Conclusion

As seen in the preceding paragraphs, advanced CNC machining offers increased precision, speed, and automation in manufacturing, resulting in complex geometries and high-quality parts. Key benefits include faster production times, reduced labour costs, and consistent accuracy, making it suitable for high-volume and intricate applications. Advanced CNC machining will become a critical pillar of smart manufacturing, enabling flexibility, efficiency, and precision.

However, advanced CNC machining also demands specialised knowledge and skilled operators, and the cost of advanced equipment can be significant. Optimising designs for CNC machining can further reduce costs and lead times. Choosing appropriate materials for CNC machining is crucial for achieving desired results. While offering significant benefits, advanced CNC equipment can be expensive, and a thorough due diligence is called for before investing in these machines, especially on the RoI front. Above all, However, success depends on embracing digital transformation holistically.

Summing up, it is a matter of achieving the right balance depending on the level of precision required for the tasks undertaken. Aerospace, high end automobiles, medical equipment, semiconductor requirements call for ultra high precision and advanced machining. On the other hand there are other requirements where such high precision is not necessary to sustain quality in routine applications. Finally, it also boils down to making manufacturing processes more efficient, precise, and sustainable.

QUALITY CONTROL IS THE TOP AI DRIVER IN MANUFACTURING FOR A GOOD REASON

Interview with Daniel Sperlich, Strategic Product Manager for Controllers in the EMEA region.

MITSUBISHI ELECTRIC
Changes for the Better

As Gartner forecasts, as many as half of the world's manufacturing companies will already be supporting themselves with AI tools for quality control of their products or components by the end of this year.

From a European perspective, quality control remains a top priority in AI-driven automation. According to "*The 2024 AI in European Manufacturing Report by Makerverse*", 79% of European manufacturers believe AI will significantly enhance production efficiency over the next five years. A closer look at the data reveals that quality control and inspection lead the way in automation priorities, with 59% of industrial companies focusing on AI to improve this area—by far the most significant investment in AI-driven manufacturing.

Undoubtedly, the emphasis on implementing AI solutions in product verification and quality control has specific reasons. We ask **Daniel Sperlich**, Strategic Product Manager for Controllers in the EMEA region at Mitsubishi Electric, about these, wanting to find out what prospects and opportunities the move to next-generation quality control opens up for manufacturing plants.

▶ **Journalist**: *Automated AI quality control is one of the fastest-growing areas of production automation. Why are European companies so eager to invest in these types of solutions?*

Daniel Sperlich: Indeed, we are observing significant interest in AI-supported automated visual inspection systems. I can say that quality control is the top AI driver in manufacturing for a good reason. Firstly, quality control is a process that directly impacts customer satisfaction and brand reputation. Every defective product that reaches the customer generates complaint costs and can damage the company's image. Rebuilding it is often very difficult and requires a series of corrective actions.

Secondly, previously employees were manual inspectors who had to check every single product. With AI visual inspection, it largely frees up these employees to focus on other activities, while guaranteeing operation with ultimate precision 24 hours a day. We know that, as humans, we have certain limitations regarding our ability to maintain concentration for extended periods, and that's why we're looking with interest at tools that can effectively support us in this regard. So I'm totally not talking about replacing human quality control, but shifting the task from 100% inspection including good products to only inspecting defective products, resulting in fewer products to be examined over a 1-day worktime. This minimizes the risk of missing defects to almost zero.

I think it's also worth mentioning the labor shortage problem constantly plaguing the industry. I recently came across a Eurobarometer survey showing that twenty-two percent of employers in European heavy industry say they can't find the workers they need. This usually means very limited quality control capabilities and even the need to slow down the production process.
Improved quality control, therefore, also means maintaining higher plant productivity and overall production cost optimization. Products with defects are immediately reported and taken off the line, reducing the risk of producing entire batches of defective products. This has a huge impact on the OEE indicator.

▶ **Journalist**: *What specific production problems can be solved through automated visual inspection?*

Daniel Sperlich: The list is quite extensive. Take our VIXIO system, for example. It can detect all sorts of defects - scratches, cracks, discoloration, incorrect textures. It checks assembly completeness - whether all components are in place.. Moreover, thanks to deep learning, the system learns to recognize increasingly new types of defects and is prepared for varying production conditions.

MELSOFT MaiLab analysis solution provides continuous monitoring of all welding points. By analyzing all welding parameters in real-time - at a rate of 1,000 welding parameters per second - the tool can detect even the smallest changes in patterns and deviations that indicate potential quality problems before they cause defects or flaws. The system achieves 97% accuracy in defect detection and 100% coverage of welding points, which can result in a 65% reduction in manual inspection time and a 40% decrease in welding defects.

▶ **Journalist**: *You mentioned deep learning. What makes AI-based systems superior to any other vision systems?*

Daniel Sperlich: Traditional vision systems operate based on rigidly defined rules and parameters. They work well for simple, repetitive tasks. But when there's greater product variability, different types of defects, varying lighting conditions they start to become very complex and require a lot of time for thorough consideration and testing-. Deep learning systems like VIXIO can learn and you can easily adopt new product variants or improve the AI Accuracy. They just need to be shown enough examples of good and defective products, and they'll "*learn*" to recognize defects, even previously undefined ones. Moreover, they become increasingly effective over time with more good product pictures and knowledge gained in practice.

▶ **Journalist**: *What does the implementation process for such a system look like? Does it require significant changes to the existing production line?*

Daniel Sperlich: We strive to implement in a totally non-invasive model. What does this mean? The VIXIO can be integrated with virtually any production line. The system consists of an industrial camera, lighting, IPC computing unit, and software and can be installed beside the already running production. Then we conduct the system training process, using samples of good and defective products. In many cases, our customers already have sample pictures that we can use even prior to the installation to prove the effectiveness of the Inspection software. The AI Creation phase normally takes only a few minutes, until it can be deployed and first tests can be started. Of course, we also provide comprehensive technical support and operator training.

▶ **Journalist**: *Which industries most frequently turn to automated visual inspection solutions?*

Daniel Sperlich: Initially, the automotive and electronics industries dominated, where quality requirements were particularly high. But currently, we're seeing great interest from practically all industrial sectors. VIXIO is used in the production of packaging, metal products, plastics, building materials, and food products. It's valuable anywhere where product quality is crucial and can be assessed based on visual characteristics.
I think we can highlight here the example of VIXIO potential in practice. The case is about the body panel inspection in automotive. After the press of the chassis parts, the whole part is then inspected on both sides. If anything happened during the process, may it be a slight displacement of the metal sheet, material defects etc. had to be inspected by the worker at the final station. Together with robots, that task is now possible to automate with AI visual inspection.

▶ **Journalist**: *How do you see the future of quality control in manufacturing?*

Daniel Sperlich: The trend is clearly moving towards full automation and AI integration. We're seeing increasing interest in predictive quality control, where systems not only detect defects but also predict potential quality issues before they occur. The integration of visual inspection with other Industry 4.0 technologies - for example data analytics platforms like MELSOFT MAILAB. Since not all defects can be visually detected, process parameters also play an important role in predicting quality losses that, if combined, provide a powerful, allrounder inspection platform that can adapt and counteract, before serial defects can form. This creates comprehensive Quality Management Systems (QMS) that can significantly improve production efficiency and product quality.

▶ **Journalist**: *What advice would you give to companies considering investing in automated visual inspection?*

Daniel Sperlich: First, clearly define your quality control needs and challenges. Start with areas where automation of inspection processes has the biggest impact, for example in manual inspection stations. Consider not just the immediate cost savings but also long-term benefits like improved product quality, reduced waste, and enhanced customer satisfaction. It's also important to choose a solution that can grow with your business and can simply adapt to the production line and changing needs. Finally, ensure you have good support from your technology provider - proper implementation and training are crucial for success and allow rapid adoption of new products or AI improvement.

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MORE INFORMATION

MARKET OVERVIEW

RETHINKING PACKAGING:
A SHIFT TOWARD SUSTAINABILITY

Sustainable packaging is the need of the hour, given the environmental damage caused by conventional packaging materials, says Milton D'Silva.

Wikipedia describes packaging as the science, art and technology of enclosing or protecting products for distribution, storage, sale, and use. Packaging may also be described as the process of designing, manufacturing and using containers of various types for protection and safe transportation products, from the point of origin to the end users. As products are widely produced and traded, the market for packaging is huge, valued at approximately US$1.24 trillion in 2024 and projected to reach around US$1.69 trillion by 2034, expanding at a Compound Annual Growth Rate (CAGR) of 3.16%.

Today, about 40% of the packaging materials used globally are plastics, thanks to its many advantages like flexibility, durability, and lightweight nature. Estimates also suggest that roughly a quarter of all plastics produced globally are used in packaging. Plastic, as is commonly acknowledged, is not easy-to-recycle material and over 80% of it ends in landfills, creating a huge problem for the environment. This in turn has led to the need for sustainable packaging.

So what exactly is sustainable packaging, and why is it important? Sustainable packaging may be described as packaging that makes use of reusable or recyclable materials that minimise environmental impact without compromising on the ideal requirements of packaging. Sustainable packaging means reducing the use of materials and resources, also minimising energy requirements in the process.

Globally, more and more consumers are now aware of the perils of plastic packaging materials and the harm they are causing to the environment. Findings of some recent surveys on the harmful effects of plastic packaging materials on the environment have some interesting results. Over 80% of the consumers in the developed world have expressed concerns about it. This has in turn led to a demand for sustainable packaging that can minimise the environmental impact through the use of recyclable, reusable, and compostable materials, thereby reducing waste, as well as energy consumption, during production and transportation.

This article examines at length the issues associated with packaging and packaging materials, the problems caused by their rampant use in a booming consumer market, and the demand for sustainable packaging materials.

The need for sustainable packaging
Today, the environmental impact of traditional packaging materials – whether fossil fuel-based products like plastics, or plant-based materials like paper and cardboard – is all too obvious. Rampant use of these materials is leading to significant harm to the environment through pollution on the one hand, and depletion of natural resources on the other. It is also leading directly to increased greenhouse gas emissions, and serious landfill issues, causing soil and water contamination, in the process also polluting water bodies, rivers and the oceans.

The worst offender when it comes to packaging materials is plastic. As a synthetic polymer made from chemicals derived from petroleum, plastic is not a biodegradable material in nature. This means plastic cannot be broken down by natural processes, like bacteria and fungi, into simpler substances like carbon dioxide, water, and biomass. The result is a burgeoning global crisis that is causing severe environmental damage, harming wildlife, disrupting ecosystems, and posing risks to human health through toxic chemicals and microplastics.

The carbon footprint caused by packaging materials is substantial as it encompasses all greenhouse gas emissions throughout their lifecycle, from raw material extraction to final disposal. Traditional packaging materials like plastic and non-recycled paper have a higher impact due to energy-intensive production and disposal processes. According to the United Nations Environment Programme (UNEP), every day the equivalent of 2,000 garbage trucks full of plastic are simply dumped into the world's oceans, rivers, and lakes. Every year 19-23 million tonnes of plastic waste leaks into aquatic ecosystems, polluting lakes, rivers and seas. Plastic pollution can alter habitats and natural processes, reducing the ecosystems' ability to adapt to climate change, directly affecting millions of people's livelihoods, food production capabilities and social well-being.

Challenges in waste management and recycling
The challenges in managing plastic waste, or recycling it, are many. These include inadequate infrastructure, lack of public awareness, financial constraints, and inefficient collection and disposal systems, which impact the environment and public health. Most residential areas, especially in developing countries, do not have effective waste collection, sorting and processing facilities. This results in overflowing bins, haphazard collection without any segregation of waste and dumping it at landfill sites or some makeshift dumping ground. While it is possible to recycle most plastic waste, in the absence of proper business models and investments, there are no mass-scale recycling facilities. Countries like Singapore, Japan and Sweden have a very high rate of waste recycling, including plastic waste. But these are exceptions rather than the norm.

Apart from outdated garbage collection and disposal infrastructure, leading to slow operations and increased costs, the other significant challenge is a lack of public awareness and participation. Most people simply do not understand the importance of reducing waste generation, nor do they care to segregate their waste while disposing it off. This in turn, hinders the municipal efforts of effective waste management. As the cost of waste collection, transportation, and disposal can be high, especially in thickly populated urban areas, over a period of time the operations become highly inefficient and inadequate, suffering from financial constraints.

Plastic waste is polluting water bodies, rivers and the oceans. Photo by Fayegh (Shamal) Shakibayi on Usplash

Global regulations on packaging waste
Concerned over the relentless growth of packaging requirements and ballooning waste generation, most countries are getting into the act of controlling this menace. Globally, regulations on packaging waste are still evolving, but the contours that are emerging have a strong focus on reducing waste, promoting reuse and recycling, and limiting the environmental impact of packaging, particularly plastic.

Key trends and regulations can be summarised as:

- Bans and restrictions on single-use plastics: Many countries and regions are implementing bans or restrictions on single-use plastics, such as bags, straws, and certain types of packaging, to reduce waste and pollution.
- Extended Producer Responsibility: EPR schemes hold manufacturers responsible for the end-of-life management of their packaging, incentivising them to design for recyclability and reuse.
- Recycled content targets: Regulations often set targets for the percentage of recycled content in packaging, encouraging the use of recycled materials and reducing reliance on virgin materials.
- Design for recyclability: Packaging is increasingly required to be designed for recyclability, ensuring that materials can be easily separated and processed for recycling.
- Minimising packaging: Regulations aim to reduce the amount of packaging used, focusing on minimising unnecessary packaging and promoting efficient packaging solutions.
- Reusable packaging: There's a growing emphasis on promoting reusable packaging systems, such as deposit return schemes and encouraging the use of reusable containers for take-away food and beverages.

Besides these general trends, there are many country- and region-specific initiatives like the EU Packaging and Packaging Waste Regulation (PPWR), US Plastic Waste Reduction Act, Denmark's PFAS Ban, and India's Plastic Waste Management Rules – 2016, among other remedial measures.

Types of sustainable packaging
There is no dearth of sustainable packaging materials today. Even traditional packaging materials that are plant based, like paper and cardboard, are sustainable if these are sourced from responsible forestry practices. In practice, however, rampant use of plant based materials leads to deforestation, and hence, is harmful to the environment. Recycled paper products are certainly sustainable, and the

Dumping ground littered with single-use plastics. Image by Pete Linforth from Pixabay

emphasis today is on recycling most paper products used in packaging rather than sending it to landfills. There are many other options when it comes to sustainable packaging materials besides paper products, as summarised below.

1. Biodegradable and compostable materials

- PLA (Polylactic Acid) – A bioplastic derived from renewable resources like cornstarch or sugarcane, offering a biodegradable alternative to traditional plastics.
- Cellulose – Derived from natural sources like wood pulp and cotton, cellulose is a biodegradable and compostable material with moisture-resistant properties, making it suitable for food packaging.
- Mycelium Packaging – Packaging made from the root structure of fungi (mycelium) offers a sustainable alternative to traditional packaging materials.
- Cornstarch-based Foam – A biodegradable and compostable foam packaging alternative to traditional polystyrene.
- Edible Packaging – Packaging made from edible materials like seaweed or plant-based films, offering a completely waste-free solution.
- Sugarcane Pulp – A renewable and biodegradable material that can be used for packaging.

2. Recyclable materials

- Cardboard and Corrugated Paper – Highly recyclable and versatile materials for packaging, offering good strength and cushioning.
- Recycled Paper and Card – Using recycled paper and card reduces the need for virgin materials and minimises waste.
- Recycled Plastic – Using recycled plastic in packaging reduces the environmental impact compared to virgin plastic, requiring less energy to manufacture and reducing greenhouse gas emissions.
- Glass – A natural and sustainable material that is widely used to store products like moisturisers and serums due to its high recyclability.

3. Other sustainable materials

- Kraft Paper – A strong and durable paper material that is widely used in packaging, offering a sustainable alternative to plastic.
- Jute – A natural fibre that is used to make bags and other packaging materials, offering a sustainable alternative to synthetic materials.
- Wool – A natural, renewable, and biodegradable material that can be used for packaging.

Biodegradable and compostable packaging

The various categories of materials classified as biodegradable and/or compostable are not always what they seem. To be considered biodegradable, the material must decompose by the action of living organisms such as microbes (bacteria, fungi), into water, carbon dioxide, and biomass. For packaging materials to be considered truly biodegradable, they should ideally break down within a year or less, ideally within months, under composting conditions, transforming into water, carbon dioxide, and biomass through the action of microorganisms. Otherwise, all materials are inherently biodegradable, whether it takes a few weeks or a million years to break down into organic matter and mineralise. To that extent, there is a lot of misrepresentation and greenwashing by companies to present their products as more environment-friendly than they actually are. The most widely used petroleum-based plastics such as polyethylene terephthalate (PET), polyethylene (PE), polypropylene (PP), and polystyrene (PS) are not biodegradable. Yet there are a few petroleum-based plastics that are considered biodegradable. These include: Polyglycolic acid (PGA), Polybutylene succinate (PBS), Polycaprolactone (PCL), Poly(vinyl alcohol – PVA, PVOH), and Polybutylene adipate terephthalate (PBAT).

Similar is the case with compostable materials. While compostable plastics biodegrade, they are specifically designed to be processed in composting facilities, which provide the necessary conditions (temperature, moisture) for decomposition. Without these industrial composting facilities, the materials do not really break down into their natural constituents and stay in the environment as harmful particles or microplastics, which today have been found in human bloodstream.

Minimalist and zero-waste packaging

One practical solution that is gaining popularity when it comes to sustainable packaging is the minimalist approach – using the least amount of materials with innovative design elements. The supermarkets are full of farm produce stacked on endless shelves wrapped in layers of plastic and then placed in styrofoam containers. Minimalist packaging focuses on simplicity and efficiency, using only what's necessary to protect the product and convey essential information. It eliminates unnecessary layers, fillers, and decorative elements to minimise waste by considering only the protection and functionality of the packaging, rather than flashy aesthetics. Minimalist packaging also promotes only recyclable or compostable materials like kraft paper, cardboard, or biodegradable plastics.

The other alternative, zero-waste packaging, is even more radical – simply minimise or altogether eliminate waste by using reusable, recyclable or compostable materials. Gas cylinders – domestic and industrial – are fine examples of reusable packaging, also used for water in large containers in many places. Above all, zero-waste packaging is focused on totally eliminating the use of single-use plastics that contribute most to environmental pollution. By promoting responsible use of resources, this helps reduce waste and protect ecosystems.

Innovations in sustainable packaging

Innovations in sustainable packaging today focus on advanced materials and coatings like biodegradable and compostable polymers, mycelium-based packaging, and edible coatings, alongside smart packaging with sensors and data carriers, all aiming at reduced environmental impact and increased functionality.

A range of advanced materials like PLA (polylactic acid), PHA (polyhydroxyalkanoates), and thermoplastic starch

offer alternatives to traditional plastics, breaking down naturally in compost or industrial settings. Mycelium-based packaging that uses the root-like structure of fungi (mycelium) to create biodegradable and sustainable packaging, offers a natural and renewable alternative to polystyrene. Then there are Cellulose Nanocrystals, which are derived from agricultural waste. These nanocrystals offer lightweight, strong, and renewable packaging alternatives. There are also bioplastics – plastics made from renewable resources like corn, sugarcane, and potatoes, which can biodegrade in the environment.

When it comes to coatings, there are various options one can choose from:

- Edible Coatings: Coatings made from natural polymers that can be eaten along with the product, reducing the need for traditional plastic packaging.
- Water-Soluble Films: Films that dissolve in water, offering a sustainable alternative to traditional plastics.
- Biodegradable Coatings: Coatings that provide water resistance, gloss, and durability to packaging materials while also being biodegradable.

Smart packaging, earlier restricted to very expensive and sensitive consignments, is another emerging trend that has now entered the packaging arena. Thanks to innovative technologies and benefits of economies of scale, smart packaging integrates technology into packaging to improve sustainability, such as smart labels, NFC chips, RFID, and QR codes, for product authentication and connection. This is supplemented or augmented by active packaging – packaging that includes active components to enhance food preservation and quality, such as sensors to monitor freshness or biosensors to detect spoilage. Besides, there is nanotechnology applied in coatings to formulate edible coatings and improve their performance, safety, and storage.

Towards circular economy

Unlike traditional economies where resources are harvested or mined, made into products, and then become waste, the Circular Economy envisages elimination of waste by keeping products in circulation for as long as possible. This is achieved by a combination of superior design of materials, products, and systems at the manufacturing stage, and maximising reuse and recycling over the life cycle. Like the minimalist approach, the circular economy model also aims at transforming packaging by reducing waste and promoting reuse. However, the user industry must also take the lead by sourcing sustainable materials, recycled products or bio-based options to take this forward.

How exactly would these practices improve packaging efficiency, reduce environmental impact, and support long-term sustainability goals? By challenging the traditional linear approach of 'use and discard' in favour of a sustainable strategy focused on 'reduce, reuse and recycle'.

Wooden pallets are used extensively. Image by Freepik

Ecommerce companies are leading the drive for sustainable packaging. Image source: Amazon Shipping

Key principles of a circular economy for packaging:

- Reduce: Minimise the amount of packaging used by designing lighter, more efficient packaging or eliminating unnecessary packaging altogether.
- Reuse: Design packaging for multiple uses, such as reusable containers or bottles, or explore refill and return programs.
- Recycle: Ensure packaging is designed for recyclability, using materials that are readily recyclable and supporting robust recycling infrastructure.

Packaging-as-a-service

A notable sustainable packaging trend making a comeback is Packaging-as-a-Service (PaaS), where the focus is on reusable and refillable packaging systems. Under the PaaS model, vendors provide reusable and returnable packaging solutions to businesses. This is not exactly a new trend as much before the popularity of cheap plastic packaging took over, an early model of reusable packaging existed, especially for milk in glass bottles, which was in a way the forerunner of the PaaS model. In the basic PaaS model, businesses rent or lease packaging instead of buying it, which can significantly boost sustainability by reducing waste, promoting circularity, and optimising resource use, offering a more eco-friendly alternative to traditional packaging practices.

How exactly does the PaaS model work in practice? Since this is basically a Subscription or Rental model, companies subscribe to a service that provides them with packaging for their products. The packaging is designed to be durable and reusable, often for multiple trips. The service provider collects the used packaging from customers and cleans and redistributes it. In essence, the PaaS models minimise waste by eliminating the need for single-use packaging and promoting a circular economy. By reusing packaging, companies can reduce their reliance on raw materials and energy consumption associated with packaging production.

AI and other technologies in sustainable packaging

AI and emerging technologies can significantly boost sustainable packaging by optimising material usage, streamlining processes, enabling smart packaging, and improving recycling efficiency, ultimately leading to reduced waste and environmental impact. AI-driven systems can precisely measure and cut packaging materials, ensuring minimal excess and maximum use. AI-powered analytics can analyse vast amounts of supply chain data, identifying areas for reducing packaging waste and improving efficiency. AI algorithms can optimise packaging layouts, enhancing material efficiency and minimising excess packaging.

AI-powered systems can track products in real-time, improving safety and reducing loss. For example, AI-powered vision systems can detect defects or irregularities in packaging materials, ensuring high-quality packaging and reducing waste. Apart from AI, robotics and intelligent machines can streamline packaging processes, reducing material wastage and boosting overall efficiency. Smart packaging solutions can also incorporate sensors and data analytics to monitor and control factors like freshness, temperature, and shelf life, ensuring optimal product condition.

Challenges and barriers to adoption

Widespread adoption of sustainable packaging solutions faces numerous challenges. As happens with many problems that are waiting for effective solutions, cost ranks as the numero uno challenge as sustainable packaging materials and processes often come with a higher upfront cost compared to conventional options. Consumers used to cheap plastics are loath to pay more even with growing awareness, and manufacturers invariably push this additional cost in the cause of sustainability to the consumers. An effective via media has to be found with suitable regulatory mechanisms.

The next significant barrier is infrastructure limitations, as finding and securing sustainable materials can be challenging, leading to supply chain disruptions apart from increased costs. The (as yet) smaller demand for sustainable packaging compared to conventional packaging means lower production volumes, which can lead to higher per-unit costs. Moreover, not all products can be packaged in sustainable materials, and the availability of certain sustainable materials can be limited. A more serious issue is not all sustainable packaging materials offer the same level of protection or shelf life as conventional materials.

The third challenge pertains to regulatory mechanisms and uncertain or unclear policies. Different regions and countries have different regulations and standards for sustainable packaging, making it difficult for businesses to comply with all requirements. Also there is often a lack of clear policy guidelines and standards for sustainable packaging, making it difficult for businesses to know what is considered sustainable.

Finally, there is skepticism on part of the consumers, especially regarding the claims made about the sustainability of certain packaging materials or processes. Many consumers may also not be aware of the environmental impact of their packaging choices or the benefits of sustainable packaging. Consumers used to fancy packaging with multiple layers may well be reluctant to switch to sustainable packaging if it is inconvenient or if they perceive it as being of lower quality.

Future trends and opportunities

As mentioned earlier, today climate change and the need to rein in rising temperatures leading to global warming have sensitised consumers to the perils of damage caused to the environment. As a result, the demand for sustainable packaging has gathered momentum. Sustainability has now become an important factor influencing purchase decisions across the world. This trend has received a boost with the rise of ecommerce companies, who are now leading the drive for sustainability in packaging. Not only are these companies adopting eco-friendly materials and optimising packaging sizes, they are also using innovative technologies like QR codes for recycling information, and at the same time reducing waste and emissions.

In the contemporary scenario, the emerging trends in sustainable packaging include innovative materials like biodegradable plastics and seaweed-based packaging, reusable systems, minimal designs, and smart packaging solutions. Together, these offer opportunities for businesses to reduce environmental impact and meet consumer demand for eco-friendly products. Prominent among innovative materials are biodegradable and compostable materials, signalling a shift away from traditional plastics. These include alternative materials like plant-based plastics (PLA), mushroom packaging, and seaweed-based packaging. This is complemented by increasing use of recycled products to reduce reliance on virgin materials and promote a circular economy. Two other emerging trends are mono-materials, which simplifies packaging design by using single materials instead of laminates and composites to improve recyclability; and edible packaging, a recent and revolutionary solution, which offers a sustainable and consumer-friendly approach to food packaging. Other trends like reusable packaging systems such as returnable containers and refillable packaging, and refillable packaging options also promote sustainable consumption patterns.

The quest for alternative packaging materials. Photo by Boxed Water Is Better on Unsplash

Summing up

The drive for sustainable packaging is unfolding through increasing consumer demand, stricter regulations, and companies adopting innovative, eco-friendly solutions, with a focus on reducing waste and promoting circularity. According to a recent research report published by Towards Packaging, a global consulting firm, the sustainable packaging industry is set to grow from US$294.30 billion in 2024 to US$557.65 billion by 2034, at a 6.6% CAGR. Going forward, the objectives of sustainable packaging can be achieved by a combination of growing environmental consciousness and the willingness of consumers to pay a little more for their purchases on account of eco-friendly products and packaging. This will have to be complemented by the willingness of companies to prioritise sustainability with a commitment to the environment, and above all, appropriate policy initiatives backed by legislation aimed at reducing packaging waste, particularly single-use plastics, and promoting the use of recycled and biodegradable materials.

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TOUCHPOINT, INC. APPOINTS STACI KROON AS PRESIDENT AND CEO

TouchPoint, Inc. is excited to announce the appointment of Staci Kroon as their new President and CEO, reporting directly to TouchPoint's Board of Directors, effective March 1, 2025. Brian McNeill, who has served as TouchPoint's President and CEO for 25 years, will retire effective March 1, 2025, and transition to Executive Chairman of the Board of Directors.

Staci is an accomplished leader of global engineering and manufacturing companies, where she has excelled in driving growth and delivering results through innovation, geographic expansion, acquisitions, team building and operational excellence. Most recently, she served as President and CEO of BraunAbility, a global leader in mobility transportation solutions, providing independence to individuals with mobility challenges.

Staci holds a Bachelor of Science degree in Mechanical Engineering from the University of Pennsylvania, Bachelor of Science in Economics with a concentration in Finance from the Wharton School of Business, and a Postgraduate degree in Design, Manufacturing, and Management from Cambridge University, Cambridge, UK. Staci served on the Board of BraunAbility and currently serves on the Board of Winnebago Industries, a longtime Southco customer.

Staci said "*I am thrilled to join TouchPoint as President and CEO, stepping into a new chapter of growth and innovation alongside a talented team. TouchPoint has a remarkable 125-year history, built on a foundation of strong values, resilience, and continuous evolution.*"

After 25 years as serving as TouchPoint's President and CEO, I could not be more excited about this transition and to mark the beginning of our next 125 years of growth," said Brian McNeill. "*Our businesses are strong and well positioned to continue in their growth trajectory under Staci's leadership.*"

https://southco.com

INNODISK LAUNCHES ITS FIRST PCIE GEN5 SSD SERIES FOR HIGH-PERFORMANCE DATA CENTER APPLICATIONS

New PCIe Gen5 SSDs feature high-speed performance, up to 128TB capacity, multi-form factor support, and compliance with OCP NVMe v2.0 for AI, analytics, and virtualized environments.

Innodisk, a leading industrial-grade flash storage provider, announces the launch of its latest PCIe Gen5 SSD series, designed to meet the OCP Data Center NVMe SSD spec v2.0 and the increasing demands of AI model training, big data analytics, and data-intensive environments.

The new series supports multiple form factors, including U.2, as well as EDSFF E1.S, E3.S, and the brand-new E3.L for data center applications, catering to the diverse needs of enterprise and data center environments. This marks a new chapter for Innodisk in further fulfilling enterprise demands.

The Innodisk PCIe Gen5 SSD, built with the latest PCIe Gen 5 x4 interface and NVMe 2.0 protocol, overcomes the speed and latency limitations of traditional storage interfaces. With up to 128TB of high-density NAND storage, it delivers speeds of up to 14GB/s (read) and 10GB/s (write), enabling lightning-fast data transfers for data-intensive applications.

Enterprise data centers managing large-scale storage deployments and multi-tiered environments often require out-of-band and batch management capabilities, which present growing challenges. Innodisk PCIe Gen5 SSD addresses these demands with NVMe-MI for streamlined SSD management and multi-namespace support, ensuring scalable and efficient storage operations.

To ensure high quality and alignment with market trends, the PCIe Gen5 SSD aims to enhance integration with industry-leading data center standards, such as OCP Data Center NVMe SSD spec v2.0. Additionally, it is intended to be built for seamless integration with VMware, optimizing compatibility with virtualized environments and overall system performance.

Innodisk's PCIe Gen5 SSD also features advanced security mechanisms, ensuring robust data protection and seamless integration. Secure Boot technology authenticates digital signatures during firmware updates, preventing unauthorized modifications and ensuring that only trusted firmware is executed.

Other than that, Innodisk offers exceptional extensive firmware compatibility and customizable solutions, ensuring seamless integration into diverse enterprise environments.

The Innodisk PCIe Gen5 SSD will be available starting Q2 2025.

www.innodisk.com

ADVANCED RAILWAY
SIGNALLING AND CONTROL SYSTEMS

The future of railway signalling lies in continued innovation, collaboration, and investment in cutting-edge solutions, says Milton D'Silva.

The Industrial Revolution of the late 18th century laid the foundation for modern railways by introducing two key elements: the steam engine and tracks. However, it was not until 1804 that the first steam-powered railway train ran at the Penydarren ironworks in South Wales, UK. The first regular passenger train service began in 1830, connecting Manchester and Liverpool. Around the same time, the United States was developing its own rail system, commonly referred to as a 'railroad'.

Early railway signalling relied on simple methods such as hand signals, flags, lamps for nighttime use, and revolving boards. Since trains were few and operated on fixed schedules, these basic signalling techniques were sufficient. However, as railway traffic increased and trains became more frequent, this rudimentary system quickly proved inadequate, necessitating more advanced signalling solutions.

Effective railway signalling and control systems are crucial for safe and efficient train operations. These manage train movements, help prevent collisions, and optimise capacity on rail lines through features like automatic train protection, centralised control, and real-time communication, enhancing passenger safety and operational reliability.

The evolution of railway signalling systems

The history of railway signalling began with the opening of the Manchester-Liverpool railway in 1830, when hand signals were used initially, but soon was replaced by movable signals with the revolving board. One of the most interesting developments in the early days was the semaphore signals, patented in the early 1840s by Joseph James Stevens, which became the most widely used mechanical signal system. The semaphore signal basically used a pivoted arm to display different indications to train drivers by changing the angle of the arm. Semaphore signals were used widely until the early 20th century, and are still in use at a few places, with some modifications. As railways became a popular mode of transport and the network spread rapidly, the signalling systems also gradually evolved in stages, from the development of fixed lineside signals, followed by electric telegraphs and later, the interlocking mechanisms for points and signals. Power signalling appeared at the turn of the 20th century, and was followed by the development, first of electrical, and then electronic signalling systems. Today communication-based systems are more prevalent with digital interfaces.

The evolution of railway signalling systems is thus a journey from basic mechanical controls to highly sophisticated digital automation, ensuring safer and more efficient train operations, as can be seen from the evolutionary stages described in the following paragraphs with the approximate timelines:

Early mechanical signalling (19th Century - Early 20th Century)

The earliest railway signalling systems were manual and mechanical, relying on human operators and physical signals to control train movements. The main developments during this period were:

- Time Interval System (Pre-1850s): Trains were spaced apart based on time intervals, relying on the operators' judgment. This method was unreliable and prone to accidents.

- Semaphore Signals (Mid-1800s - Early 1900s): Rotating arms were used to indicate whether a train should stop or proceed. These arms were controlled manually from trackside signal boxes.

- Fixed Block System (Late 19th Century): Tracks were divided into fixed sections (blocks), allowing only one train per block at a time to prevent collisions.

- Interlockings: These were introduced to ensure safe route settings by mechanically linking signals and switches.

Electric & relay-based signalling (Early to Mid-20th Century)

The introduction of electricity and relays automated many railway operations, making signalling systems more reliable. Key advancements include:

- Track Circuits (1872 - Early 1900s): Allowed automatic train detection by sending electrical currents through rails. Signals could now be automatically cleared or set to danger based on train occupancy.

- Electromechanical & Relay Interlocking (Early 1900s - 1950s): Replaced mechanical interlocking with electrical

The introduction of electricity and relays automated many railway operations. Photo by Markus Winkler on Unsplash

MARKET OVERVIEW

relays, increasing efficiency. Allowed for centralised control over wider railway networks.

- Colour Light Signals (1920s - 1960s): Replaced semaphores with electric light signals, improving visibility. Enabled automated aspects like approach control, where signals adjusted based on train speed and track occupancy.

Electronic & computer-based signalling (Late 20th Century – Early 21st Century)
As computing power increased, railways adopted microprocessors and digital control to further automate and optimise train operations. Major innovations during this period:

- Solid-State Interlocking (SSI) (1980s - Present): Used microprocessors instead of relays, allowing more complex, fail-safe signal control.
- Cab Signalling (1970s - 2000s): Train drivers received speed and movement instructions directly in the driver's cab, reducing reliance on trackside signals.

- Automatic Train Protection (ATP) (1990s - Present): Prevented speeding and unauthorised train movements by enforcing safety parameters.

- Communications-Based Train Control (CBTC) (2000s - Present): Used radio signals to continuously monitor train positions, enabling moving block operation (trains running closer together safely).

- Positive Train Control (PTC) (2000s - Present, USA): Enforced speed restrictions and prevented signal violations via digital monitoring.

The modern digital age (21st Century – Future)
Railway signalling has now entered the fully digital, AI-driven era, integrating real-time data, automation, and predictive analytics. The Cutting-Edge Technologies used include:

- ERTMS (European Rail Traffic Management System) & ETCS (European Train Control System): Standardised digital signalling across Europe, allowing interoperability between countries. Level 2 and Level 3 use wireless communication to replace physical signals.

- AI & Predictive Analytics: Uses big data and machine learning to predict track failures and optimise train scheduling.

- Digital Twin Technology: Creates virtual simulations of railway networks to test and optimise signalling systems before deployment.

- 5G & IoT-based Signalling: Enables real-time data exchange between trains and control centers, improving efficiency and response time.

This gradual transformation of railway signalling from manual operations to AI-driven automation has drastically improved safety, efficiency, and capacity. The future will see even more reliance on wireless communication, autonomous train operations, and predictive maintenance, making rail transport smarter and more reliable.

The semaphore signal basically used a pivoted arm. Image by Tabble from Pixabay

Computer-based interlocking signalling system Smartlock 400. Photo credit: Alstom

Modern railway signalling technologies
The concept of automatic train control (ATC) emerged in the early 1900s, when the Great Western Railway in the UK implemented an early system in 1906. When first launched, the ATC in general, and its later derivative systems like Automatic Train Protection (ATP) and Automatic Train Operation (ATO), significantly enhanced railway safety and efficiency by preventing accidents caused by human error and optimising train operations. These were followed by the development of more advanced systems like the Automatic Train Stop (ATS) in the 1920s and 30s.

The basic purpose of ATC, which was an advanced railway signalling system of that era, was to automate train operations to improve safety, efficiency, and reliability. ATC consisted of three key subsystems:

- Automatic Train Protection (ATP) – Ensured trains operated within safe speed limits, which prevented collisions by enforcing speed restrictions, stopping trains if necessary.

- Automatic Train Operation (ATO) – Automated train acceleration, deceleration, and station stopping for smooth operation, though human oversight was still required in many systems.

- Automatic Train Supervision (ATS) – Managed train schedules, optimised train flow, and adjusted operations in real-time based on demand and disturbances.

What in effect the ATC achieved was help smoothen rail traffic with:

- Optimised train spacing, ensuring trains maintain safe headways (the distance between trains), reducing congestion and minimising delays.

- Precise speed control by adjusting train speeds dynamically based on track conditions, reducing sudden braking and improving ride comfort.

- Efficient train scheduling with coordinated train movements in real-time to maximise throughput and minimise waiting times.

- Reduced human error, as automation minimised the risk of accidents due to operator fatigue or mistakes.

- Improved energy efficiency with smooth acceleration and braking patterns thereby reducing energy consumption.

- Better response to disruptions with real-time monitoring that allowed quick rerouting and adjustments in case of delays or breakdowns.

Later, a modern railway signalling system called 'Communications-based train control' (CBTC) was introduced in the mid-1980s with the objective to achieve maximum capacity while maintaining the safety requirements. CBTC improved upon ATC by using real-time wireless communication to precisely track train positions and speeds, while enabling dynamic control of train movements. It also reduced the need for extensive trackside

equipment, ultimately leading to increased safety, capacity, and operational efficiency. CBTC relies on continuous, bi-directional communication between trains and trackside control systems to optimise train movement. Today CBTC is primarily used in metro and urban rail networks, and is deployed in metro networks like the New York Subway, London Underground, Shanghai Metro, and Paris Metro among others, to improve service efficiency.

Key features of CBTC:

- Continuous train location tracking – Unlike conventional track circuit-based systems, CBTC uses onboard sensors (like transponders or odometry) and radio communication for real-time train positioning.
- Flexible headways – Can reduce the gap between trains, allowing higher frequency service without compromising safety.
- Driverless operation – Enables fully automated (Grade of Automation 4 - GoA4) driverless train operation, reducing operational costs and human errors.
- Precise speed and stopping control – Ensures smooth acceleration, deceleration, and precise station stopping, improving passenger comfort.

How CBTC improves rail traffic flow:

- Dynamic headway adjustment: Allows trains to run closer together, increasing network capacity.
- Real-time traffic management: Adapts to disruptions, optimising train movements dynamically.
- Seamless integration with urban transport: Works well in congested metro systems where high efficiency is required.

Even as CBTC was implemented elsewhere, transport authorities across Europe were working on a master plan for a trans-European high-speed rail network in the late 1980s, when the idea for the European Train Control System (ETCS) took shape. ETCS is a standardised mainline railway signalling system developed as part of the European Rail Traffic Management System (ERTMS). It replaced fragmented national signalling systems of European countries to allow interoperable, cross-border railway operations.

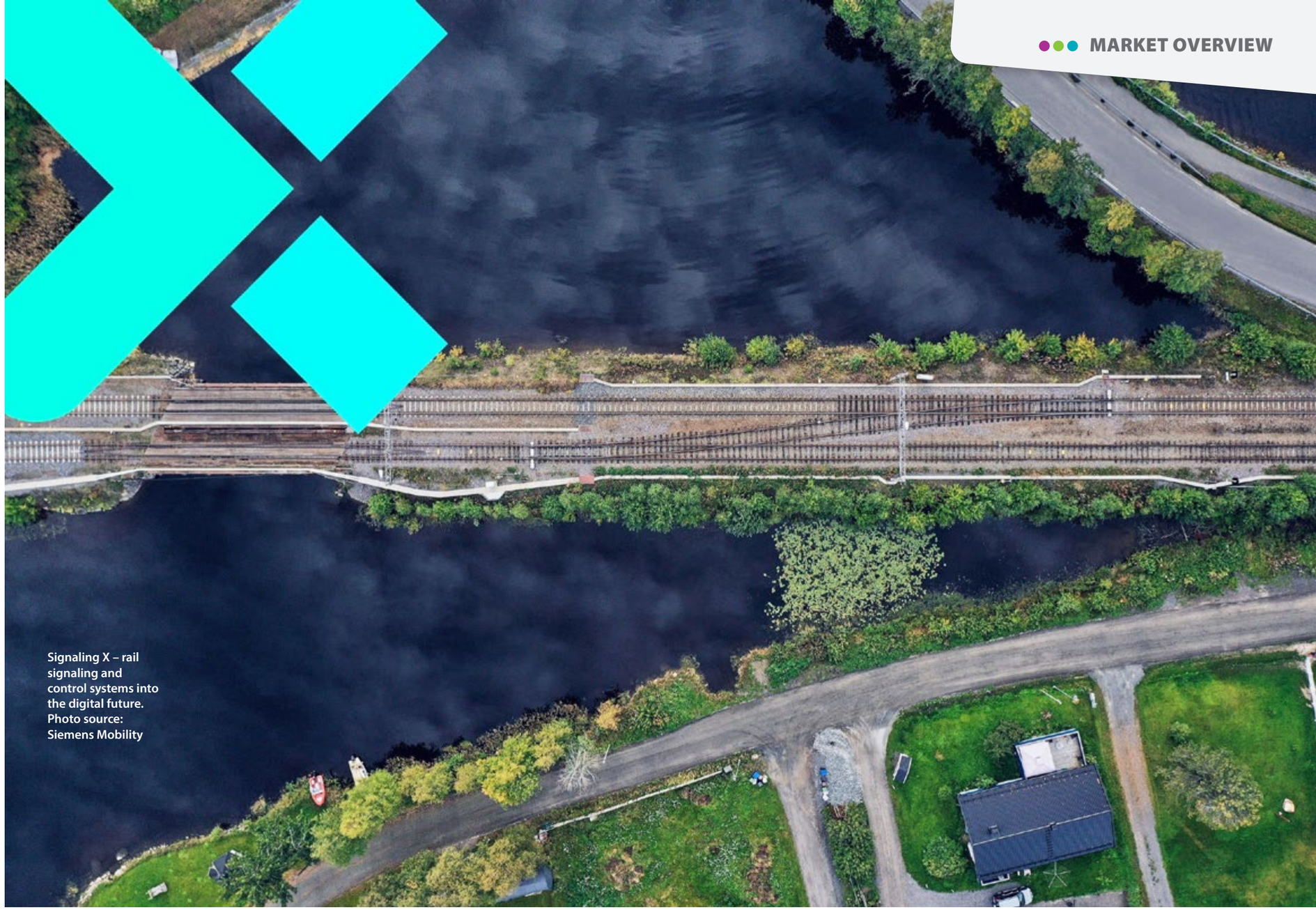
Key features of ETCS:

- Multiple levels of automation: Level 1 – Fixed block-based system with intermittent data updates via balises (trackside beacons); Level 2 – Continuous communication via GSM-R, allowing higher speeds and reduced signal dependency; and Level 3 – Full train-to-train communication, removing fixed blocks and maximising track capacity (still under development).
- Interoperability across countries: ETCS standardises signalling across Europe, allowing seamless train travel between nations.
- Enhanced safety: Prevents speeding, enforces braking curves, and ensures compliance with route permissions.
- Supports high-speed rail: Enables safe operation of high-speed trains (>300 km/h).

How ETCS improves rail traffic flow:

- Reduces signal reliance: Digital communication allows smoother train operations without needing fixed signals.
- Optimises train speeds & spacing: ETCS adjusts train speeds dynamically to prevent bottlenecks.
- Increases track capacity: ETCS Level 3 (future implementation) will eliminate fixed blocks, allowing more trains on the same track.

Today ETCS is widely deployed on European high-speed networks, including in France (TGV), Germany (ICE), and the UK (HS1 & HS2). It is also being adopted in China, Australia, and parts of the Middle East for high-speed and freight rail efficiency.



Signaling X – rail signaling and control systems into the digital future. Photo source: Siemens Mobility

Key components of advanced railway signalling systems

Regardless of the individual systems used by different operators, advanced railway signalling systems operate with the help of certain key components. These include:

- Centralised traffic control (CTC) – A centralised system that monitors and manages train movements across a railway network. Operators can control signals and track switches remotely to optimise traffic flow.
- Interlocking systems – Interlocking systems are essential in railway signalling to prevent conflicting train movements through junctions, switches, and crossings. They ensure that signals, track switches (points), and level crossings operate in a coordinated and safe manner by preventing conflicting movements. There are different types of interlocking systems ranging from the early systems like Mechanical interlocking; later improvements such as Relay-based or Electromechanical interlocking; or the latest Electronic Interlocking (EI) or Computer-Based Interlocking (CBI) systems.
- Train detection systems – These ensure track occupancy monitoring to prevent accidents. Key technologies for train detection include: i) Track circuits – Detecting presence of trains using electrical circuits; ii) Axle counters – Counting

MARKET OVERVIEW

wheelsets to confirm train location; and iii) Radar & LiDAR sensors – Used in modern, high-tech railway applications.

- Positive Train Control (PTC) – This is a US-based safety system designed to prevent train collisions, derailments, and speed violations. It uses GPS, trackside sensors, and onboard computers for real-time monitoring.

- Trackside signalling equipment – Includes traditional colour light signals, LED signals, and mechanical semaphore signals; also balises (transponders) and beacons for communication with onboard systems.

- Wayside & onboard communication systems – These use GSM-R (Global System for Mobile Communications – Railway), LTE-R, and future 5G networks. They enable real-time communication between trains and control centres.

- SCADA (Supervisory Control and Data Acquisition) – for monitoring and control of power supply, signalling, and infrastructure remotely. This provides real-time diagnostics to prevent failures.

- Cybersecurity & data analytics – Modern signalling systems integrate AI-driven analytics for predictive maintenance. Cybersecurity measures are implemented to protect against hacking and system failures.

Benefits of advanced railway signalling and control systems

When it comes to a mass transport system like the railways that carry millions of passengers worldwide every single hour, safety is of paramount importance. Advanced railway signalling and control systems are crucial for ensuring safe, efficient, and reliable train operations by preventing collisions, regulating speeds, and optimising traffic flow through automated signals and communication technologies. Enumerated below are some of the key benefits of signalling and control systems in railway networks:

i. Enhanced Safety

- Collision prevention: Automatic Train Protection (ATP) and Positive Train Control (PTC) systems prevent collisions by enforcing speed limits and stopping trains if necessary.

- Reduced human error: Advanced signalling minimises the risks associated with driver fatigue or misjudgment.

- Real-time monitoring: Centralised control systems provide continuous monitoring, allowing immediate response to potential hazards.

ii. Increased Railway Capacity

- Optimised train spacing: Systems like Communication-Based Train Control (CBTC) and European Train Control System (ETCS) allow for shorter headways between trains, increasing line capacity.

- Higher frequency of services: More efficient use of track infrastructure enables increased service frequency without additional tracks.

iii. Improved Operational Efficiency

- Automated Train Operations (ATO): Reduces delays by ensuring precise acceleration, braking, and stopping.

- Energy efficiency: Smart control systems optimise speed profiles and braking to reduce energy consumption.

- Predictive maintenance: Condition-based monitoring detects potential failures before they cause disruptions.

iv. Enhanced Passenger Experience

- Reduced delays: Efficient train scheduling and real-time adjustments help minimise service disruptions.

- Better information systems: Real-time train tracking and automated announcements improve passenger communication.

v. Seamless Interoperability

- Standardisation across networks: Systems like ETCS and CBTC enable cross-border train operations, supporting international rail travel.

- Integration with other transport modes: Smart signalling can coordinate rail services with buses, metros, and trams for smooth multimodal travel.

vi. Cost Savings

- Lower maintenance costs: Digital signalling reduces the need for physical trackside equipment, cutting maintenance expenses.

- Optimised workforce deployment: Automation reduces dependence on manual intervention, streamlining operations.

Challenges in implementing advanced signalling systems

The tools of technology are available for the railway signalling systems as they are for other aspects of modern living. Yet, implementing advanced signalling systems in digital railway networks presents several challenges across multiple dimensions. The following paragraphs present an overview of some of these challenges in terms of implementation and maintenance costs, infrastructure upgrades, software integration, cybersecurity risks, and interoperability/standardisation issues.

i. Challenges in implementation and maintenance costs

- High initial investment: Advanced signalling systems such as ETCS and CBTC require substantial financial investment in hardware, software, and operational modifications.

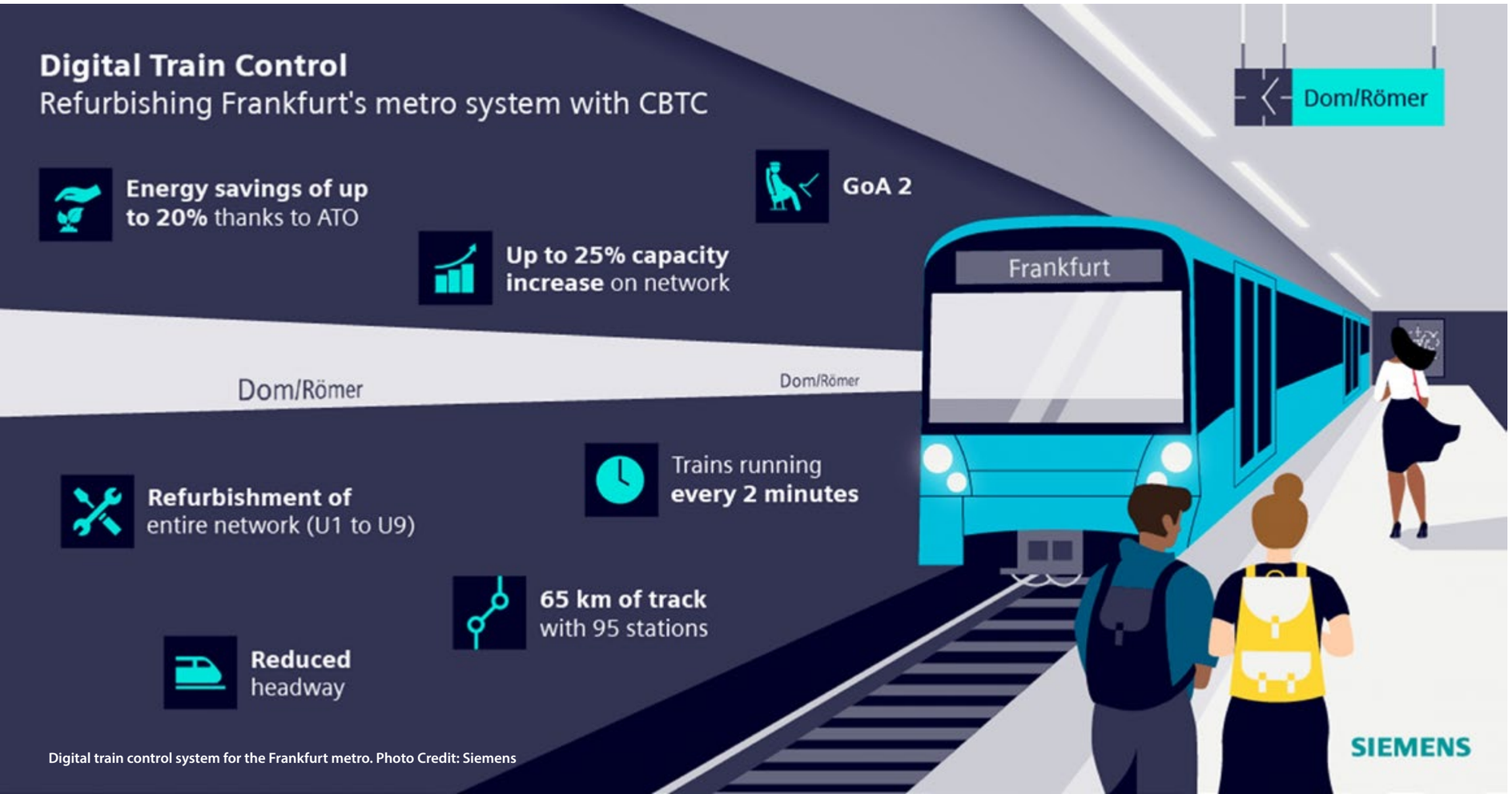
- Cost of retrofitting existing systems: Older railway networks require extensive modifications, including upgrading legacy signalling infrastructure, which can be expensive and time-consuming.

- Ongoing maintenance expenses: Modern digital signalling relies on continuous software updates, sensor recalibration, and system diagnostics, increasing lifecycle costs.

- Return on investment (RoI) considerations: Operators may struggle to justify the high upfront costs, especially in regions with lower railway traffic density or limited government funding.

ii. Challenges infrastructure upgrades

- Compatibility with legacy systems: Many rail networks still rely on traditional relay-based or analog signalling, making digital integration complex and costly.



Digital train control system for the Frankfurt metro. Photo Credit: Siemens

- Need for high-quality communication networks: Advanced signalling depends on robust, low-latency communication networks (e.g., 4G/5G, fiber optics). Ensuring uninterrupted connectivity across vast railway networks is a challenge.

- Power supply and redundancy: Many railway lines require enhanced power distribution systems to support new signalling technologies, adding to infrastructure costs.

- Trackside equipment modernisation: Deployment of sensors, beacons, and transponders along tracks is necessary for digital systems, which can be logistically challenging in remote areas.

iii. Challenges in software integration

- Integration with existing train control systems: Different railway operators use varied legacy software, requiring complex and costly integration with modern signalling solutions.

- Real-time data processing & synchronisation: Digital signalling depends on real-time data exchange between trains, control centers, and trackside equipment. Ensuring data consistency is critical but technically complex.

- Software bugs and system failures: Any glitches in automated signalling software can lead to service disruptions, posing operational and safety risks.

- AI & predictive maintenance complexity: While AI-driven predictive maintenance can improve efficiency, implementing and training such systems requires significant expertise and investment.

iv. Challenges in cybersecurity risks in digital railway networks

- Increased vulnerability to cyberattacks: As railways become more digitised, they become attractive targets for cybercriminals, including ransomware, data breaches, and system sabotage.

- Lack of cybersecurity awareness and standards: Many railway operators still lack comprehensive cybersecurity strategies, making systems vulnerable to attacks.

- Third-party risks: Signalling systems often rely on software and hardware from multiple vendors, increasing the risk of supply chain vulnerabilities.

- Potential safety risks: A cyberattack could disrupt signalling, potentially leading to train collisions or derailments.

- Challenges in incident response: Coordinated incident response across multiple stakeholders (railway operators, government agencies, cybersecurity teams) is difficult due to jurisdictional and technical barriers.

v. Challenges in interoperability and standardisation issues

- Diverse signalling systems across countries & operators: Rail networks worldwide use different signalling protocols, such as ETCS in Europe, CBTC in metros, and PTC in the US, leading to interoperability issues.

- Lack of unified standards for digital signalling: While global initiatives (e.g., ERTMS for high-speed rail) aim to standardise systems, regional variations still exist.

- Cross-border operations complexity: Trains traveling across international borders must switch between different signalling systems, requiring costly multi-system onboard equipment.

- Vendor lock-in risks: Some operators depend on proprietary signalling solutions from specific vendors, making future upgrades and integrations difficult.

- Harmonisation challenges: Aligning multiple national and regional railway authorities under a single digital signalling standard remains a significant hurdle.

Potential solutions

- Global standardisation initiatives (e.g., full-scale adoption of ERTMS/ETCS Level 3 to unify signalling across regions).

- Mandating open-source or interoperable systems to prevent vendor lock-in.

- Collaboration between railway authorities and technology providers to ensure smoother transition strategies for legacy systems.

Future trends and innovations in railway signalling

In a world of rapidly evolving technologies, no solution is permanent as there is always room for improvement. The current generation of railway signalling and control systems are quite advanced and sophisticated, but still there are shortcomings that become obvious when incidents occur, some leading to loss of lives. On January 5, 2024, two trains collided near Cicalengka Station in Bandung Regency, Indonesia, resulting in four fatalities and 42 injuries. The collision was attributed to an uncommanded signal leading to a false clear, caused by aging hardware in the signalling system. In June 2024, a collision occurred in the State of West Bengal in India involving a passenger train, the Kanchanjunga Express, and a freight train. The freight train reportedly ignored multiple red signals, leading to the crash. However, some sources suggest that a faulty automatic signal, defective since early morning, may have contributed to the incident. More recently, in early March 2025, services between London Paddington and Reading, as well as Heathrow Airport, were suspended due to a signalling fault, causing much chaos and delays in services during peak hours.

So what exactly are the future trends and innovations for a foolproof railway signalling system? Once again, new and emerging technologies offer some effective solutions in this context, which are summarised below.

Artificial Intelligence and Machine Learning (AI and ML) could offer some solutions based on:

- Predictive maintenance: AI-driven analytics can predict failures in signalling equipment, reducing downtime and enhancing safety.

- Automated Train Operation (ATO): AI optimises train movements, ensuring smooth acceleration, braking, and scheduling.

- Real-time anomaly detection: Machine learning models analyse vast amounts of signalling data to detect faults and optimise routes dynamically.

Next, satellite-based train control systems are also evolving, with possible solutions including:

- GNSS-based signalling: GPS and Galileo enhance train positioning, reducing reliance on trackside equipment and enabling cost-effective operations.

- ERTMS evolution: satellite technology improves the European Rail Traffic Management System (ERTMS), enhancing train tracking and control.

- Remote monitoring & operations: satellite-based systems enable real-time monitoring of remote railway sections, improving safety and efficiency.

Advances in 5G and edge computing in railway networks could offer more options such as:

- Ultra-low latency communication: 5G enhances real-time train-to-ground communication for faster and more reliable signalling.

- Edge AI for decentralised control: Edge computing processes signalling data closer to the source, reducing delays and improving decision-making.

- Enhanced passenger safety & experience: 5G enables high-speed connectivity for surveillance, infotainment, and smart train operations.

Conclusion

In conclusion, advanced railway signalling and control systems are revolutionising the global rail industry by enhancing safety, optimising efficiency, and increasing network capacity. The adoption of technologies such as the European Train Control System (ETCS), Positive Train Control (PTC), and Communication-Based Train Control (CBTC) is enabling more precise and automated operations, reducing human error, and ensuring seamless interoperability. As rail networks continue to modernise, integrating AI, IoT, and digital twin technologies will further transform railway operations, making them smarter, more sustainable, and resilient to future demands. The future of railway signalling lies in continued innovation, collaboration, and investment in cutting-edge solutions that will drive the industry toward a more connected and intelligent transportation ecosystem.

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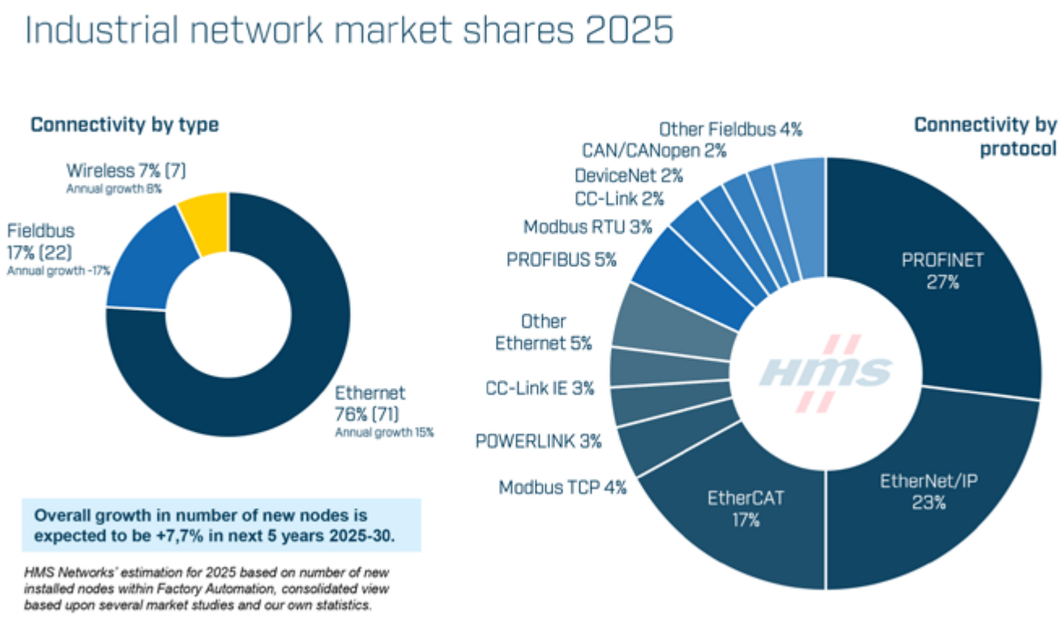
ANNUAL HMS NETWORKS REPORT CONFIRMS GROWING DOMINANCE OF INDUSTRIAL ETHERNET

In the 2025 study, HMS concludes that the industrial network market continues to grow, with total market growth over the next five years estimated at +7.7%.



Magnus Jansson VP Marketing HMS IDS Division

HMS Networks has released its annual analysis of the industrial network market, revealing key trends and developments. After an exceptional surge in 2023, the market experienced a slight slowdown in 2024, with a decrease of approximately 10–11% in newly installed nodes. This dip is primarily attributed to a more challenging economic environment, ongoing uncertainties, and excess production capacity in highly automated sectors such as automotive and manufacturing, particularly in Europe.

Despite the overall slowdown, the study confirms that Industrial Ethernet continues to strengthen its position, while traditional fieldbus technologies are declining at an accelerating pace. During the past two years, shortages in electronic components sustained the demand for serial-based fieldbus solutions as companies turned to any available technology. However, with components now more readily available and economic pressures mounting, the focus has shifted toward more cost-efficient and scalable Ethernet-based communication.

In the 2025 study, HMS concludes that the industrial network market continues to grow, with total market growth over the next five years estimated at +7.7%. Although 2025 is expected to be below this average due to current market conditions, a ramp-up is anticipated in the following years, confirming the continued importance of network connectivity in factories.

Ethernet-based networks now represent 76% of new installations

The 2025 analysis shows that Ethernet-based industrial networks now account for 76% of new nodes, up from 71% in 2024.

Leading the Ethernet pack:
- PROFINET strengthens its lead at 27% (up from 23%)
- EtherNet/IP follows at 23% (up from 21%)
- EtherCAT continues a strong trajectory at 17% (up from 16%)
- Modbus TCP holds steady at 4%
- POWERLINK, CC-Link IE, and other Ethernet networks remain stable, with slight adjustments

Fieldbus technologies now represent just 17% of new nodes, down from 22% in 2024.

Within Fieldbus:
- PROFIBUS remains the largest but drops to 5% (from 7%)
- DeviceNet, CC-Link, and Modbus RTU each decline by 1 percentage point
- CAN/CANopen holds steady at 2%
- Other Fieldbus protocols collectively make up 4%

Wireless remains steady a 7%

Wireless technologies interconnect 7% of new node installations, remaining stable compared to 2024. Wireless continues to be an important complement for non-real-time critical communications, mainly for use cases requiring mobility, flexible networking, or hard-to-reach areas such as in AGVs (automated guided vehicles), mobile industrial equipment, and retrofitting legacy systems.

5G wireless technology, currently implemented for mobile telecom usage, is still experiencing slow adoption in industrial automation. This is due to the complexity of infrastructure management, high implementation costs, and challenges in achieving affordable real-time performance in cellular chips. However, despite these barriers, early industrial deployments, particularly in Asia, are already underway, and the technology holds exciting potential for the future of industrial communication.

Regional insights
- Europe: Strong adoption of PROFINET and EtherCAT, with increasing interest in new infrastructure technologies like APL (Advanced Physical Layer) to enable Ethernet communication for process automation applications, and SPE (Single Pair Ethernet) for Ethernet communication up to sensors.
- North America: EtherNet/IP remains the leading protocol in North America, but adoption of smart device-friendly technologies like IO-Link, APL, and SPE is clearly growing, with strong market momentum expected in the coming years.
- Asia: PROFINET and EtherCAT are both growing in the Chinese market, while CC-Link IE, the first industrial protocol with TSN mechanism, maintains a strong regional foothold.

HMS Networks' perspective

"*This year's data clearly confirms the ongoing shift from traditional fieldbuses to Industrial Ethernet. It's a transition driven by the need for more modern network capabilities in today's automation systems,*" says Magnus Jansson, VP Marketing at HMS Networks. "*While Industrial Ethernet is now well-established, we still see strong growth due to an appetite for more information and the digitalization of the industry. The Ethernet infrastructure also paves the way for further innovation toward gigabit Ethernet, TSN, Single Pair Ethernet, and OT/IT convergence.*"

The average growth expectation over the coming 5 years is estimated at 7.7%, despite the short-term political and economic uncertainties and upcoming cybersecurity regulations that will force automation companies to rethink the way they connect automation systems.

About the study

The HMS Networks analysis is based on a combination of market insights, internal data, and input from key stakeholders in the industrial automation industry. The study focuses on newly installed nodes in factory automation worldwide, each node being a device or machine connected to an industrial control network.

www.hms-networks.com

ADVANCEMENTS IN FLEXIBLE PACKAGING AUTOMATION

K.A. Gerardino explores how flexible packaging automation is transforming industries by boosting productivity, precision, and cost efficiency in high-demand sectors.

Flexible packaging automation is redefining modern packaging operations, emerging as a key solution for industries seeking higher productivity, precision, and cost savings. This technological evolution is particularly significant in high-demand sectors, such as food and beverage, pharmaceuticals, personal care, cosmetics, and consumer goods, where speed, flexibility, and safety are non-negotiable. At its core, flexible packaging automation involves the integration of advanced machinery and intelligent systems to manage the entire packaging process—from filling and sealing to labeling, inspecting, and palletizing—using flexible materials like pouches, shrink films, bags, and wraps instead of traditional rigid packaging such as boxes or bottles.

A Booming Global Market

The flexible packaging sector is experiencing unprecedented growth. In 2024, the market size reached an estimated US$141.03 billion. According to the IMARC Group, this figure is projected to grow to US$242.85 billion by 2033, at a compound annual growth rate (CAGR) of 3.51% from 2025 to 2033. The Asia Pacific region currently leads the global market with a commanding 45.8% share in 2024, driven by rising industrial activity, rapid urbanization, and government support for local manufacturing. This expansion is further bolstered by increased demand for sustainable solutions, consumer preferences for convenience, and breakthroughs in automation and smart packaging technologies.

Why Flexible Packaging Automation Matters

Flexible packaging automation brings multiple operational advantages that are shaping the future of the packaging industry. As demand grows for faster, more sustainable, and more customized packaging solutions, automation offers a strategic response to these evolving needs.

Efficiency and Speed: One of the most significant benefits of automation is the ability to dramatically increase production throughput. Automated systems streamline operations by integrating functions such as feeding, filling, sealing, and labeling into a cohesive workflow. This reduces cycle times, minimizes downtime, and significantly cuts down on manual labor requirements. As a result, manufacturers not only lower operational costs but also mitigate risks associated with human error and fatigue. In high-demand sectors like food and pharmaceuticals,

Image by Tunisit from Pixabay

this efficiency can be a game-changer for meeting tight deadlines and maintaining product integrity.

Consistency and Quality Control: Automated machinery ensures uniformity and precision in critical packaging processes like sealing, cutting, and filling. These systems eliminate variations that often occur with manual handling, resulting in consistent packaging outcomes. Advanced vision inspection technologies and sensors are frequently integrated into the lines to detect defects, misalignments, or inconsistencies in real-time. This leads to higher product quality, fewer returns or complaints, and stronger brand reliability across production batches.

Adaptability and Customization: Today's packaging lines are built for agility and responsiveness. Modern machines are equipped for rapid changeovers and intuitive controls, allowing manufacturers to efficiently handle a variety of SKUs, package sizes, and materials. Whether switching from pouches to flow wraps or accommodating seasonal promotional designs, automation makes it easy to respond to changing customer demands and shorter product life cycles. This adaptability is particularly crucial in industries with frequent product innovation or customized offerings, such as cosmetics, snacks, and nutraceuticals.

Sustainability: Automation plays a vital role in supporting sustainability initiatives. By enabling accurate dosing, precise sealing, and optimized cutting, these systems help reduce excess material usage and minimize waste. Furthermore, many modern automated packaging lines are compatible with recyclable, compostable, and biodegradable films, allowing companies to align their operations with increasingly stringent environmental regulations. Smart energy usage and reduced resource consumption also contribute to a smaller carbon footprint, enhancing the company's overall sustainability profile.

Scalability: Whether a company is a small startup or a large multinational corporation, automated packaging systems can scale seamlessly with production growth. Modular system designs and flexible configurations allow for incremental upgrades and expansions without the need to completely replace existing infrastructure. This scalability ensures that automation remains a future-proof investment, capable of supporting business growth, increased product lines, and evolving market demands over time.

Key Drivers of Growth

The flexible packaging industry is experiencing accelerated growth due to a combination of technological innovations, shifting consumer preferences, and broader market dynamics. Several key drivers are shaping this momentum across global markets, particularly in the United States.

E-Commerce Boom and the Shift to Flexible Formats

The explosive growth of online shopping continues to be a major catalyst for the flexible packaging industry. Lightweight, durable, and space-saving, flexible packaging minimizes shipping costs, reduces the risk of product damage during transit, and enhances the overall customer experience with easy-to-open and resealable features. These advantages are especially relevant in the age of e-commerce, where efficient last-mile delivery and appealing unboxing experiences can influence customer loyalty.

In the United States, where approximately 76% of adults shop online regularly, brands are under pressure to balance cost-effective shipping with visually appealing and functional packaging. Flexible formats offer that perfect balance, allowing e-commerce businesses to optimize both logistics and customer satisfaction. The surge in subscription-based models for food, beauty, and health products further underscores the need for reliable, protective, and flexible packaging solutions that can withstand frequent handling and variable storage conditions.

Changing Consumer Behavior and Urbanization

The U.S. market remains a powerful trendsetter in packaging innovation. With 51% of Americans categorized as middle class in 2023, there is a growing appetite for packaged products that emphasize convenience, health, and lifestyle compatibility. Consumers today value portability, resealability, and ease of use—qualities that flexible packaging inherently delivers.

Urbanization is also accelerating this trend. As more people live in cities and lead fast-paced lives, there's a rising demand for smaller, portion-controlled packaging that suits on-the-go consumption. Flexible packaging, which is often lighter and easier to store than rigid formats, has become the preferred choice for urban dwellers seeking functional yet attractive packaging.

Emerging Trends in Flexible Packaging

Eco-Friendly Innovations and Regulatory Support: Sustainability is no longer optional—it's a driving force behind packaging decisions. Flexible packaging solutions are evolving rapidly to meet environmental expectations. New material formulations use fewer raw resources, reduce greenhouse gas (GHG) emissions, and support a circular economy by being recyclable, compostable, or biodegradable.

Governments and regulatory agencies are playing a crucial role in accelerating this transition. In the United States, the Department of Energy allocated USD 13.4 million in 2022 to fund research into advanced recycling technologies, including chemical recycling processes that can convert mixed or contaminated plastics into usable raw materials. This kind of public-sector support is encouraging brands and converters to innovate and invest in sustainable packaging infrastructures.

Convenience and Single-Serve Packaging

Modern consumers prioritize convenience more than ever. Flexible packaging formats such as stand-up pouches, spouted pouches, and resealable zipper bags are being engineered to cater to increasingly busy lifestyles. Single-serve and portion-controlled packaging is gaining popularity not only for its convenience but also for its ability to reduce food waste and support healthy portioning.

Manufacturers are responding with new formats and sustainable materials. Industry leaders like Mars and Berry Global have developed lightweight PET jars containing high percentages of post-consumer resin (PCR), aligning with the twin goals of consumer convenience and environmental responsibility. These innovations not only meet the demands of the marketplace but also contribute to corporate sustainability commitments.

Advancements in Barrier Properties

Technological breakthroughs in film and coating technologies are paving the way for high-barrier flexible packaging that protects against moisture, oxygen, light, and other external contaminants. This is particularly critical for food, pet food, and pharmaceutical products, where shelf life and product integrity are non-negotiable.

For instance, Mondi's collaboration with Norway's Felleskjøpet on recyclable, high-barrier pet food packaging highlights how the industry is marrying sustainability with performance. These advancements ensure that manufacturers can offer eco-conscious solutions without compromising the protection, freshness, or safety of their products.

Market Segmentation Overview

The flexible packaging market is segmented across various categories, with each segment playing a crucial role in driving the industry's growth and innovation.

By **Product Type**, printed rollstock continues to dominate the market, accounting for approximately 59.7% of the global share. Its ability to be easily customized, combined with cost-effectiveness, makes it a preferred choice for high-volume operations across multiple industries, particularly in food processing and fast-moving consumer goods (FMCG). Meanwhile, preformed bags and pouches are gaining significant traction due to their user-friendly features such as resealability, ease of handling, and attractive shelf appeal. These formats cater to the growing demand for convenience among urban consumers and premium product presentation in retail environments.

By **Raw Material**, plastic remains the most widely used material, with polyethylene (PE) and polypropylene (PP) leading the way. These plastics together make up about 61.8% of the market due to their affordability, flexibility, and excellent barrier properties, which are crucial for protecting products and extending shelf life. However, in light of increasing regulatory pressure and consumer demand for

eco-conscious alternatives, paper and aluminum foil are emerging as viable, sustainable substitutes. These materials are being incorporated into newer packaging designs that aim to reduce environmental impact while maintaining functionality.

By **Printing Technology**, flexography holds the largest share at 62.7%, owing to its high-speed capabilities, low setup costs, and minimal material waste. It is especially suitable for long runs, making it ideal for large-scale manufacturers. At the same time, rotogravure and digital printing technologies are experiencing rapid growth, driven by the need for high-resolution graphics, quick turnaround times, and the ability to produce personalized or short-run packaging for niche markets and promotional campaigns.

By **Application**, the food and beverage sector represent the most dominant user of flexible packaging, accounting for an impressive 72.1% of the market. The industry's demand is fueled by the need for safe, lightweight, and easily transportable packaging solutions that also preserve freshness and enhance shelf life. Beyond food, the pharmaceutical, cosmetics, and personal care industries are also major contributors to market growth, relying on flexible packaging for its hygienic protection, tamper-evident features, and visually appealing design options.

Overall, these segmentation trends reflect the dynamic nature of the flexible packaging industry, shaped by technological progress, shifting consumer preferences, and the global push toward more sustainable materials and practices.

Regional Market Insights
The flexible packaging market is witnessing dynamic growth across all major regions, each shaped by unique economic drivers, regulatory landscapes, and consumer preferences. Understanding regional developments provides a clearer picture of global opportunities and challenges.

Asia Pacific
Asia Pacific remains the dominant force in the global flexible packaging industry, accounting for the largest share in both production capacity and consumption volume. China and India lead the charge, supported by strong manufacturing bases, rapid urbanization, and rising middle-class populations demanding packaged goods.

In China, government-led strategies such as "*Made in China 2025*" aim to elevate the country's industrial capabilities, including the development of smart and sustainable packaging technologies. Investment in automated packaging lines is also rising, especially in food, pharmaceuticals, and e-commerce logistics.

India, meanwhile, is leveraging policy initiatives such as Foreign Direct Investment (FDI) incentives in the food processing sector to boost domestic production and attract international players. With a young, digitally connected population and increasing demand for convenience foods, India's market is poised for long-term growth in flexible formats, especially stand-up pouches and resealable bags.

Southeast Asian countries like Indonesia, Vietnam, and Thailand are also gaining momentum, driven by export-oriented manufacturing and the rising adoption of eco-friendly materials.

North America
In North America, the flexible packaging sector is undergoing a transformation fueled by technological adoption, sustainability concerns, and the surging demand from e-commerce channels. Consumers are

increasingly favoring packaging that is easy to use, reduces environmental impact, and enhances shelf appeal.

The Save Our Seas 2.0 Act and other federal and state-level policies are pushing for better recycling infrastructure and innovation in packaging design. These regulations are prompting companies to develop materials that are not only recyclable but also compliant with evolving Extended Producer Responsibility (EPR) frameworks.

The U.S. and Canada are also at the forefront of digital printing, smart packaging, and automation in flexible packaging production—allowing brands to rapidly customize packaging, reduce lead times, and respond quickly to market trends.

Europe
Europe is one of the most mature and environmentally driven flexible packaging markets. The region's direction is heavily influenced by ambitious sustainability targets set by the European Union, especially under the Circular Economy Action Plan. One of its key mandates is for 55% of plastic packaging to be recyclable by 2025, placing strong pressure on manufacturers to innovate and shift toward circular materials.

As a result, there is growing investment in biodegradable, compostable, and mono-material solutions. Countries such as Germany, France, and the Netherlands are actively developing infrastructure for plastic waste collection, recycling, and reuse. Additionally, consumer awareness of sustainable practices is higher in this region, influencing brand strategies and packaging choices across industries from food to cosmetics.

Latin America
In Latin America, the flexible packaging industry is expanding, led by Brazil and Mexico, where the food and beverage sectors are driving most of the demand. Increasing urban populations, growing middle classes, and a surge in supermarket and convenience store formats are boosting the consumption of packaged foods, snacks, and beverages.

Despite challenges such as economic volatility and fragmented recycling infrastructure, there is a visible shift toward sustainable practices. Regional brands are gradually adopting recyclable and lighter packaging options, with support from NGOs and global partners that promote circular economy principles.

Middle East & Africa
The Middle East and Africa region is emerging as a promising market for flexible packaging, with government initiatives supporting industrial diversification and sustainability. Saudi Arabia's Vision 2030, for instance, is fostering innovation in local manufacturing, including eco-conscious packaging for food, pharmaceuticals, and personal care products.

Growing consumer awareness, urban development, and a rising demand for fast-moving consumer goods (FMCGs) are encouraging the transition from traditional rigid packaging to more efficient and sustainable flexible formats. Countries like the UAE, Egypt, and South Africa are also investing in smart packaging technologies and materials compatible

with regional climate challenges, such as high temperatures and humidity.

Competitive Landscape and Industry Developments
The flexible packaging automation market is becoming increasingly competitive, with key players investing heavily in research and development to drive innovation and maintain a leading edge. Global giants such as Amcor Limited, Berry Global, Mondi, UFlex, and Sealed Air are at the forefront, continually developing advanced packaging solutions that combine high performance with sustainability. These companies are not only enhancing the efficiency and functionality of automated systems but are also placing a strong emphasis on environmentally responsible materials and production methods to align with evolving regulatory requirements and consumer expectations.

Recent industry developments reflect this commitment to innovation and growth. In December 2024, UFlex announced a major expansion project in Egypt, investing US$ 200 million to increase its production capacity and strengthen its presence in the Middle East and North Africa (MENA) region. That same month, Toppan Holdings acquired Sonoco's TFP division, a strategic move aimed at bolstering its portfolio of sustainable and flexible packaging solutions. Earlier, in August 2023, Amcor expanded its footprint in the Indian market by acquiring Phoenix Flexibles, a key player in the region's flexible packaging sector. In another notable move, Huhtamaki, a global leader in sustainable packaging, invested in Emerald Technology Ventures in September 2022, signaling a clear intent to accelerate the development of next-generation eco-friendly packaging technologies.

These developments highlight a broader trend in the industry: a shift toward smarter, greener, and more efficient packaging systems. As demand for flexible packaging continues to rise globally, companies that prioritize sustainability, regional expansion, and automation will be best positioned to lead in the years ahead.

Key Technologies Shaping the Future
Several advanced technologies are driving the future of flexible packaging automation, enabling manufacturers to achieve higher efficiency, accuracy, and adaptability. Form-fill-seal (FFS) machines are at the forefront, used for both vertical and horizontal pouch filling and sealing. These machines streamline the packaging process, making them ideal for high-speed operations across various product categories. Robotic pick-and-place systems are increasingly integrated into packaging lines to automate product handling, significantly reducing the need for manual labor and increasing operational precision. To maintain consistent quality, automated inspection systems equipped with vision-based technology are employed to detect defects in real time, ensuring only properly packaged products reach the market. Additionally, the integration of smart sensors and IoT (Internet of Things) technologies allows for predictive maintenance and real-time data analytics, helping manufacturers monitor machine performance, reduce downtime, and optimize productivity. These key technologies collectively form the foundation of next-generation packaging automation.

Real-World Applications
Flexible packaging automation has become an integral part of various industries, delivering speed, efficiency, and adaptability to meet modern production demands. In the snack food industry, vertical form-fill-seal (FFS) machines are widely used to package products like chips and dried fruits at high speeds, ensuring consistency and freshness. Companies such as Ishida, Mespack, and Syntegon Technology GmbH (formerly Bosch Packaging) are leading providers of these high-performance FFS systems, offering solutions tailored for both large-scale and niche food processors.

In the pharmaceutical sector, flexible blister packing machines are essential for sealing tablets and capsules in a secure, hygienic format. Industry leaders like Uhlmann, IMA Group, and Romaco supply advanced blister packaging technologies that meet strict regulatory and quality standards, while offering integrated inspection and serialization capabilities to support pharmaceutical traceability.

Meanwhile, the e-commerce industry is embracing automated bagging systems to streamline order fulfillment. Companies such as PAC Machinery, Pregis (Sharp Packaging Systems), and Sparck Technologies offer smart bagging solutions that rapidly package clothing, accessories, and other goods, reducing labor dependency and improving order accuracy. These real-world applications demonstrate how flexible packaging automation is transforming packaging operations across diverse sectors, enabling companies to scale efficiently while meeting consumer and regulatory demands.

Challenges to Adoption
Despite its benefits, flexible packaging automation comes with challenges. These include high initial investment costs, the need for skilled operators, and integration complexities with existing legacy systems. However, these challenges are increasingly mitigated by modular, user-friendly solutions and comprehensive after-sales support from equipment providers.

Conclusion
Flexible packaging automation is more than a trend—it's a strategic imperative. With the market poised to surpass US$240 billion by 2033, companies that prioritize automation, sustainability, and consumer-centric packaging designs will lead the next decade of growth. As environmental awareness and digital commerce continue to reshape industries, flexible packaging provides a smart, scalable, and future-ready solution that aligns operational excellence with global sustainability goals.

ABB IS INTEGRATING RENEWABLES INTO THE POWER GRID

Traditional grids reliably delivered centralized power; however, decentralized renewables often located remotely require feeding electricity into the grid's edges, originally designed only for delivery.

Power grids across the world are speeding up the transition to renewables to meet net zero targets. But the success of this transition relies on adopting new approaches for traditional grids designed originally to serve large-scale fossil-fuel generation. Kristina Carlquist, Head of Synchronous Condenser Product Line, ABB Large Motors and Generators, outlines some of the challenges and opportunities that arise.

Renewable energy resources like wind and solar are transforming how we power our lives, they are clean, sustainable and growing fast. However, their increasing penetration in the global energy mix is creating new challenges for existing power grids that were never designed to handle renewables. The reason is that most of the world's grids were originally constructed at the start of the 20th century, over 100 years ago. And they were designed to serve large, centralized power stations, first burning coal and later with gas-fired or nuclear plant, with the energy flowing in one direction from the center out to the edge.

These traditional networks have served their purpose and provided an exceptional level of reliability, decade after decade. But renewable energy is very different. It is decentralized almost by definition, since wind and solar power resources are generally located far from population centers, out in the countryside or on remote hillsides or even out at sea. That means that they must feed their electricity into multiple points across the grid, often at the very edge, where the infrastructure was only designed to deliver electricity, not to receive it.

Furthermore, wind and solar power are intermittent. When the wind doesn't blow or clouds cover the sun, output can drop in an instant, with other generation or energy storage systems having to come online immediately to make up the balance. That means grids now need to be able to handle complex, multi-directional flows of electricity.

There is also another, often overlooked, factor which is that the traditional power stations have turbines – large spinning masses that play an important role in providing services to help keep grids stable should there be a sudden change such as an increase in load or plant dropping offline. In contrast, renewable energy is often converter-based. That means some intermediate processing is needed before the electricity is fed into the grid – in the case of solar panels they produce direct current (DC) that has to be changed into the alternating current (AC) used by the grid. This conversion step is why wind and solar resources are currently unable or limited in their capacity to provide grid stability services, such as inertia and fault current contribution.

When talking about renewables, hydroelectric power is an important exception. This long-established method of generation, going back to the 19th century, uses water to spin a turbine, so it can help keep the grid in balance.

These challenges certainly do not mean that renewables necessarily weaken power grids. Instead, grids need to adapt and evolve to use generating resources effectively wherever they come from, while maintaining the reliability essential to keep the lights on. The good news is that proven technologies, are available today to support this evolution, with many examples already in place and making an important contribution.

The bottom line is that the energy transition should not be seen as a threat, rather it is a huge opportunity. By using the right solutions, we can make power grids both strong and sustainable. In our next article we will cover the topic of grid stability, what it is and why it matters to our day-to-day life.

https://www.youtube.com/watch?v=7A0TE_JdmYQ

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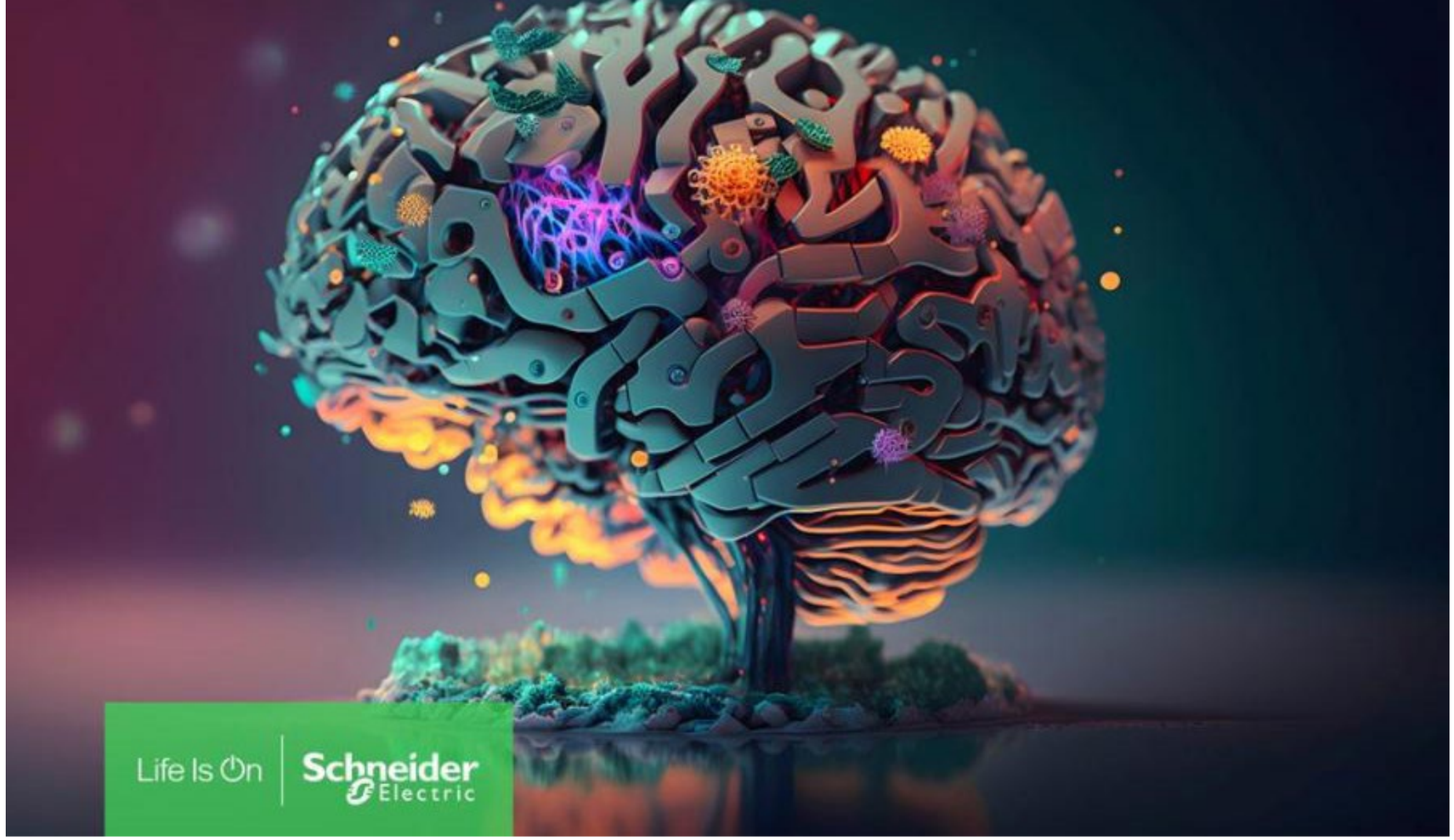
SCHNEIDER ELECTRIC LAUNCHES AI-NATIVE ECOSYSTEM FOR SUSTAINABLE ENERGY MANAGEMENT



Initiative will build a category-defining, agentic AI ecosystem empowering collaborative intelligence to drive market-leading outcomes & experiences.

Schneider Electric has announced a landmark multi-year initiative dedicated to building a new kind of integrated ecosystem for sustainability and energy management, backed by a significant growth model that represents the company's commitment to forward-thinking software and innovation.

At the core of this initiative is an emerging artificial intelligence technology known as Agentic AI. These agents are a new kind of software designed to work independently or collaboratively with clients and consultants to anticipate needs and adapt to complex environments in real time, ushering in a new era of simplification and automation in sustainability. Conventional software has historically been used as a tool to help you perform tasks, while this initiative with embedded AI agents that can do work for you, demonstrates the paradigm-shifting nature of an AI-native, agentic software ecosystem.

The company's next-generation ecosystem will reimagine energy and sustainability management by serving as both the command center and coordination layer for strategy and decision-making. By embedding AI agents into adaptive workflows that seamlessly integrate with human experts and enterprise systems, it is set to transform disconnected sustainability efforts into an intelligent ecosystem that continuously optimizes outcomes and drives sustainable impact.

Schneider Electric has appointed Julien Picaud as Head of Product Management to lead this initiative. Picaud comes to Schneider Electric with a background in strategic leadership and product management, and a focus on digital innovation and AI-focused initiatives that enhance business performance and intelligent resource and emissions management. Picaud will spearhead the investment which will reimagine core functionality from the company's existing software platforms while debuting new features from the recent acquisition of leading sustainability firm EcoAct, including:

- Decarbonization Strategy
- Scenario Analysis
- Benchmarking
- Emissions Management
- Reporting & Compliance
- Climate Risk
- Value Chain Engagement
- Energy Management
- Resource Efficiency
- Data Integration, Automation, & Visualization
- Modernized User Experience

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THE ENERGY TRANSITION'S MISSING LAYER: WHY SURFACE SOLUTIONS AREN'T ENOUGH

The global shift towards solar, wind, and hydro overlooks reliability gaps due to environmental dependency. Neutrinovoltaic tech by Neutrino Energy Group explores untapped ambient energy layers for a resilient future.

Solar, wind, and hydropower dominate discussions on sustainable energy, and rightly so. Collectively, they now provide nearly 30% of global electricity and have driven down carbon emissions in several regions. However, these sources share a common flaw: intermittency. Solar power drops to zero after sundown, and even utility-scale battery arrays struggle to store more than a few hours of demand. Wind fluctuates with atmospheric instability, and hydropower faces geographical, seasonal, and ecological constraints. Moreover, scaling these technologies in dense urban areas or remote off-grid regions presents logistical and financial challenges.

Transmission bottlenecks compound the issue. Renewable generation often occurs far from demand centers, necessitating vast investments in high-voltage transmission lines and smart-grid upgrades. The International Energy Agency estimates that over $600 billion per year will be required by 2030 just to maintain global grid performance under net-zero targets. And despite these planned expenditures, blackouts such as the 2025 Iberian incident have exposed the fragility of centralized infrastructure, even in advanced economies.

Introducing the Ambient Energy Layer
Where traditional renewables interact with the Earth's surface and atmosphere, ambient energy technologies extend the search for usable energy deeper into the quantum fabric of space. Neutrinos, once thought massless and unreactive, are now known to carry kinetic energy and pass through every square centimeter of Earth at rates exceeding 60 billion particles per second. Unlike photons, which require direct line-of-sight to a source, neutrinos permeate solid matter unhindered. Their omnipresence makes them a non-intermittent energy medium, available everywhere, at all times.

This insight underpins the Neutrino® Energy Group's neutrinovoltaic breakthrough. Rather than using heat or sunlight, neutrinovoltaic cells exploit nanomaterials—notably multi-layered graphene composites doped with silicon—that resonate when struck by neutrinos and other forms of non-visible radiation. These resonances induce a weak electric current that, when scaled across numerous cells, becomes a usable power source.

Crucially, this technology does not require any external fuel, produces zero emissions, and remains fully operable in complete darkness, underwater, underground, or in sealed enclosures. In energy terms, it is the first technology that genuinely detaches power generation from environmental variability.

From Particle Discovery to Practical Power
The viability of this approach stems from decades of cross-disciplinary advances. The 2015 Nobel Prize in Physics, awarded to Takaaki Kajita and Arthur B. McDonald for proving that neutrinos have mass, laid the theoretical foundation. Material science provided the next leap: multi-layer graphene structures, known for their extraordinary electron mobility and mechanical strength, became the basis for neutrinovoltaic transducers. The Neutrino® Energy Group refined these materials into stable, modular arrays capable of producing a continuous output of 5–6 kW via its flagship device, the Neutrino Power Cube.

These devices have now entered pre-industrial field testing. In Europe, dozens of Power Cubes are being installed in urban and off-grid scenarios, including data relay stations, remote clinics, and critical infrastructure. Unlike solar or wind installations, the Power Cube can be delivered, installed, and operational within days, with no connection to any grid or external storage required.

Power Without Infrastructure: The Case for Leapfrogging
This infrastructure-independence opens a profound opportunity for developing economies. Much of the global population still lacks reliable electricity, especially in Sub-Saharan Africa, South Asia, and isolated parts of Southeast Asia. Traditional electrification strategies rely on extending grid networks, often over hostile terrain and at exorbitant cost. In many cases, building a high-voltage line to a rural community costs more than the economic output it could enable.

Neutrinovoltaic systems offer an inversion of this paradigm. With no need for grid extension, substations, or fuel logistics, countries can deliver permanent, clean electricity by deploying modular neutrinovoltaic devices directly at the point of use. These deployments are not only faster and cheaper; they are also inherently secure from cyberattacks, blackouts, and theft.

The implications for education, agriculture, public health, and digital inclusion are vast. Clinics can operate vaccine refrigeration without generators. Schools gain consistent power for digital curricula. Irrigation pumps and sensor networks can be powered without diesel imports or seasonal volatility. Small businesses in energy-isolated regions could finally operate at full potential.

Filling the Gaps in the Clean Energy Stack
Electrification will dominate global decarbonization pathways. But to fully electrify industrial processes, transport fleets, and digital infrastructure, power generation must evolve from reactive to proactive. Weather-tied renewables are only one part of the equation. The other is a new class of technologies that decouple energy availability from externalities.

Neutrinovoltaics fill this role. Not as a replacement for solar and wind, but as a stabilizing constant that underpins their variability. Just as hydrogen and battery storage are positioned to smooth short-term fluctuations, neutrinovoltaic generators offer long-term baseline output. Their durability, silence, and autonomy make them ideal for hybrid deployment—complementing variable renewables and reducing overbuild.

Moreover, the decentralization of neutrinovoltaic systems complements energy democracy. Power is generated where it's used, with minimal losses. This redefines national energy planning: grid architects can reduce redundancy, lower transmission losses, and harden against systemic failures.

The Next Energy Class: From Concept to Category
Much as photons gave rise to photovoltaics, the emerging class of ambient radiation-based energy marks a new scientific horizon. This class encompasses not only neutrinos, but other weakly interacting particles and electromagnetic remnants. The tools to harness them are still developing, but the blueprint has been drawn.

The Neutrino® Energy Group stands at the forefront of this new category. Alongside the Power Cube, the company is co-developing the Pi Car—a vehicle concept embedded with neutrinovoltaic layers to continuously recharge itself from ambient radiation. The ambition is not merely to build better devices, but to challenge the underlying assumptions of energy systems: that generation must always follow demand.

In a post-surface energy model, generation precedes demand, is constant, and is independent of physical conditions. It is this paradigm that must accompany our current climate targets if we are to go beyond stabilization and into regeneration.

Beyond the Surface
The sustainable energy transition cannot remain surface-bound. Solar and wind will continue to play a leading role, but their constraints are now widely understood. Achieving the Paris Agreement's goals and delivering universal energy access will require layering traditional renewables with non-intermittent, infrastructure-light systems. Neutrinovoltaics, by harnessing the hidden flows of the universe, offer precisely this missing layer.

www.neutrino-energy.com

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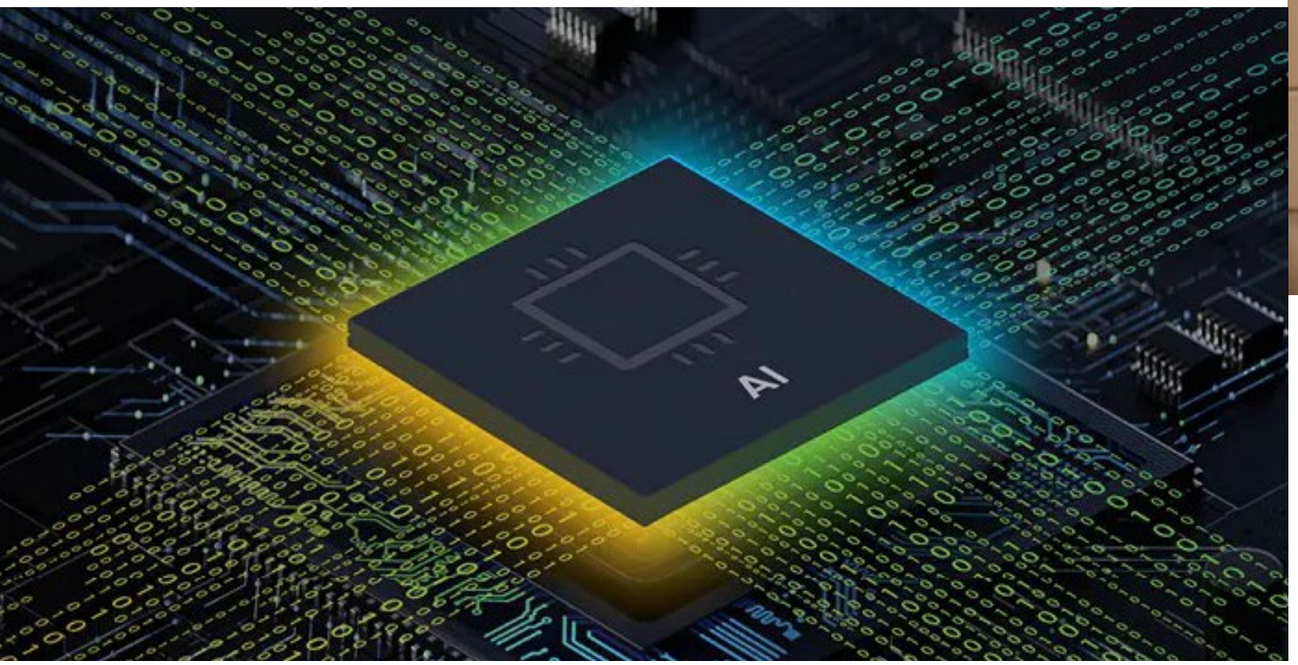
ENABLING RESPONSIBLE EDGE AI DEPLOYMENT WITH NXP



Discover NXP's approach to responsible enablement of Edge AI, focusing on ethical considerations, privacy, security, and fairness in embedded machine learning applications.

While some are thinking about how to make AI work in the first place, NXP is looking beyond, asking the question: how do we keep AI working in a safe, reliable and responsible way? This is where Responsible AI takes center stage, working with technology, government and business leaders to become a reality.

Imagine you are driving in your car to meet with friends, excited to enjoy your favorite dinner. It's been a while since you've seen them, so you want to look your best, but as you drive an alarm keeps going off, and you can't understand why. The alert notifications you're receiving are from your vehicle's driver monitoring system (DMS), telling you that you are not paying close enough attention, even though you are driving well.

Unbeknownst to you, the reason that these scenarios happen is due to the training data used by the Artificial Intelligence (AI) models powering the computer vision in the vehicle. For some reason, somehow, the AI model misunderstood its live input due to bias in training data that indicates female drivers are more often classified as "*distracted by personal grooming*", which is a result of subtle misrepresentations of people during its training.

Risks to Responsible Edge AI Development

This is not just an example of the risks of using AI to analyze data and make predictions; it's an example of the fairness and robustness issues with AI/ML systems and how they can influence modern life. In the same way that an individual may be denied financial services based on incorrect biases present in training data, edge AI can also lead to discrimination when the proper measures and risk assessments aren't taken. The intelligent edge plays a crucial role in connecting the physical world to the digital one. Physical AI, the topic at the intersection of generative AI and robotics, can only be created through edge devices, and not the cloud alone. Therefore, the risks of AI misalignment at the edge require extra scrutiny to prevent physical harm and discrimination.

The world is at a critical juncture when it comes to AI in everyday life. In January 2025, a Boston Consulting Group survey found that 75% of C-Suite executives named AI as a top 3 strategic priority for 2025. At the same time, less than one third of companies have upskilled less than one-quarter of their workforce to use AI, highlighting the immediate need for education and awareness.

Edge AI, the Responsible Way

While many companies are thinking about how to make AI work in the first place, at NXP, we are looking beyond, asking the question: how do we keep AI working in a safe, reliable and responsible way? This is where Responsible AI takes center stage, working with technology, government and business leaders to become a reality.

Responsible AI is not one, distinct and separate technology, nor is it a collection of policies and best practices. Responsible AI permeates every facet, both technical and non technical, be it machine learning, generative AI and language models, time-series data, computer vision and voice recognition; all types of intelligent software, sensors and hardware. The risks of AI impact businesses and individuals—responsible AI must represent both parties equally.

Therefore, it takes a concerted and comprehensive effort to bring Responsible AI into practice. At NXP, we have examined the topic through the lens of edge AI enablement. As a leader in the intelligent edge, we've authored a white paper on Responsible AI Enablement.

The goal of the white paper is to make recent legislation like the EU AI Act more accessible and interpretable, discuss and address risks with edge AI, highlight the roles and responsibilities of SoC vendors and give an overview of how NXP is already contributing to responsible AI through SW and tooling. For example, in the DMS example mentioned earlier, NXP is developing Explainable AI (XAI) software as part of our eIQ® Toolkit that helps detect biases after model training, before deployment. This will help prevent discrimination, ensure robustness and enable developers to identify risks early and receive an explanation.

There are many ways in which edge AI can benefit humanity; increased automation and productivity, safe and more sustainable transportation and more resource-efficient computing. Responsible enablement plays a crucial role in making sure the benefits of AI at the edge are maximized while minimizing any possible harm.

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OPTICAL TECHNOLOGY OFFERS FARMERS NEW WAYS TO BOOST OUTPUT

ams OSRAM

Optimized optical emitters and sensors from ams OSRAM help growers to manage resource use better and raise yields.

The farming industry is being squeezed from multiple directions at the same time. Hampered by the scarcity of key resources – like fresh water, and people to cultivate and harvest crops and to tend livestock – farmers are also facing the demand to increase production to meet the food needs of a global population which is predicted to rise from 8.2 billion today to 9 billion in 2037. The world's population is expected to peak at 10.3 billion in the mid-2080s, according to a United Nations forecast.

Climate change and population pressure have given rise to previous 'green revolutions', which have increased yields through the improved use of fertilizers, more intensive mechanization, and genetic breakthroughs, breeding seed varieties which produce more tonnage per hectare while being more resilient against drought, disease or other stress factors. The big gains via these methods have been made, however, and these technological fixes now offer diminishing returns. It is time for agriculture to adopt new smart technologies in the farm of the future.

These smart technologies include lighting for indoor farms, light sensors for non-destructive testing of produce, and optical navigation systems for agriculture robots. ams OSRAM is ready to put its optical semiconductor technology at the service of this industry on which every person on the planet depends.

How optical technologies impact modern farming

- Easing water stress with optimally lit indoor farms
- Minimizing food waste with non-destructive inspection
- Advanced automation eases burden on stretched workforce
- Better for society, better for the grower

Easing water stress with optimally lit indoor farms

According to a 2024 paper in the Journal of Water Process Engineering, 'severe scarcity of water is faced by around 4 billion people'. Factors such as global warming and urbanization are important causes of water shortages, but the paper says that 80 to 90 percent of all fresh water is consumed by agriculture, while its water use efficiency is on average just 45 percent.

The need to conserve water has given impetus to the growing number of indoor farms and greenhouses. This is due to the fact that these installations can implement a closed-loop water process, collecting the vapor released by crops and recycling it for use in irrigation.

Indoor farms serving local urban communities and growing perishable crops such as salad leaves, tomatoes, and strawberries help to reduce the climate impact of agriculture by dramatically cutting food miles, as cultivation takes place close to consumers and points of sale.

Indoor farming is becoming more and more economically attractive thanks to improvements in the application of highly efficient LEDs – sometimes LEDs with a white light output, but increasingly combinations of blue and hyper-red emitters which provide the most efficient growing light.

LEDs from ams OSRAM are highly valued for their quality as well as their wall plug efficiency, which is a measure of how much electrical energy is directly converted into light. Quality in horticultural LEDs strongly affects productivity: a luminaire that allows for tightly controlled emission of a plant-specific wavelength mix, intensity and beam pattern enables growers to reliably optimize illumination for each plant species, helping them to produce the highest yields with the lowest possible energy input. In addition, research has shown that active, spectrally optimized illumination allows for a substantial reduction in the amount of pesticides applied to crops.

In greenhouses, LED lighting is also being combined with light sensors which measure how much sunlight is reaching a crop, and even analyze the spectral characteristics of the ambient light. With this data, growers can determine when to supplement natural sunlight with LED lighting to provide the optimal intensity and color of illumination to the plants, while saving energy and cost by turning off or reducing the intensity of the artificial lighting whenever sufficient ambient light is available.

Depending on the distance, dTof or proximity sensors can play their part here too, by measuring the distance between a plant and a luminaire: as the plant grows towards the lamp, the power fed to the LEDs can be reduced. This takes account of the higher leaves' tendency to shade the lower part of a plant. Without this ability to adapt the output in response to the proximity of a plant, the luminaire produces more light than the plant can use for photosynthesis, resulting in the waste of electrical energy.

Minimizing food waste with non-destructive inspection

According to the UN Environment Programme (UNEP), 1.05 billion tonnes of food waste were generated globally in 2022, amounting to 132kg per person. The UNEP says that out of the total food wasted in 2022, 60 percent happened at the household level, with food services responsible for 28 % and retail for 12 %.

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Waste also occurs further upstream, when crops are in transit from the farm, and even at the farm itself. This is due in part to the difficulty for growers of shipping products through complex supply chains. With sometimes weeks between harvesting and the product appearing on the supermarket shelf, growers have to perform long-range forecasting of the time it will take their crop to ripen. Picked too late, the crop could have perished before it reaches the customer, adding to the mountain of food waste. Picked too early, the crop will not have reached full size, limiting the yield and threatening the grower's profit.

Near infrared (NIR) spectrometry provides a way to monitor the condition of crops all the way from farm to fork, helping to reduce the waste which occurs when food products perish before consumption. NIR spectrometry is an established branch of science for materials analysis. It can be used to measure the sugar and water content of crops such as fruit: these measurements provide a gauge of the fruit's ripeness.

The spectrometer operates non-destructively, by measuring reflections from an NIR light source directed at the crop in question. Traditionally NIR spectrometry has required huge, expensive laboratory equipment, unsuitable for use on the farm, in the warehouse, or in the supermarket.

Now, however, chip-scale spectral sensors offering sensitivity in the visible and NIR spectrums can be integrated into low-cost, portable spectrometers for use by growers, food processors and retailers. There are numerous applications for spectral sensors such as the AS7343, from harvesting to sorting to merchandising.

New research describes the scope for spectral and optical sensing in indoor farming as well, for example to analyze plant tissues, evaluate crop quality and yield, measure nutrients, and assess plant responses to stress.

Advanced automation eases burden on stretched workforce
Drones are commonly used for top view vision solutions on ground structures or to inspect inaccessible areas like wind turbines, while robots support tasks in manufacturing and logistics. But in fact both technologies can help to provide a solution for the looming shortage of agricultural workers.

Particularly in the highly industrialized parts of the world, the population is aging, and the ratio of retired people to active workers is rising. So competition for people of working-age is becoming more acute across all sectors of the economy. This trend is certainly being felt in agriculture: European Union research shows that 57.6% of farm managers in Europe were older than 54 years of age, while only 11.9% were under the age of 40. European agriculture faces a workforce crisis as today's cohort of farmers enters retirement.

Automation can do much to mitigate the effect of the scarcity of farm workers. Robots today are in use for cultivation functions such as weeding and sowing. Mounted on a robot, powerful light sources such as blue lasers can be used to kill weeds, and ultraviolet LEDs to prepare soil for sowing, reducing the use of pesticides. Artificial intelligence (AI) will increasingly enable robots to distinguish plant types by analyzing pictures of leaves captured by robust image sensors.

To release farm workers from tasks such as weeding, sowing and ploughing, robots and tractors will need to navigate autonomously: here, an array of ranging and detection sensors enable the device to 'see' its environment, detect and avoid objects, and perform simultaneous location and mapping functions.

Automation can also take flight with drones, allowing the farmer to map and monitor their fields from their farm office desk. Optical sensor technology comes into play here too: for example, short-wavelength infrared (SWIR) sensor technology can measure the moisture in soil from high up in the air, and cameras allow for remote monitoring of the condition of crops in the fields.

Better for society, better for the grower
The application of advanced optical semiconductors promises to enable a new generation of tech-savvy farmers to increase productivity and automate operations, while reducing their use of inputs such as water, pesticide and fertilizer. By embracing the potential of innovative optical technology, farming can continue to feed a growing global population, even in the face of the challenges of climate change and ageing populations.

Download Horticulture_2023Einzelseiten
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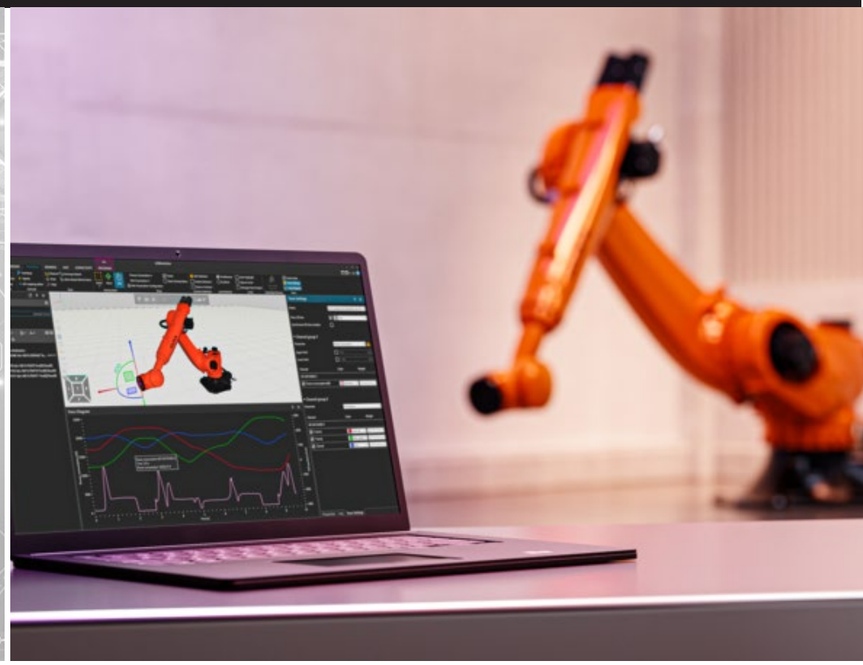
KUKA STAGES AUTOMATICA 2025 UNDER THE MOTTO ‘MAKING AUTOMATION EASIER’



KUKA

Under the motto ‘Making automation easier’, KUKA will be presenting at automatica 2025 how well decades of experience can be combined with the latest technologies to make access to robotics and automation even easier.

Automation and robotics are considered complex. KUKA proves the opposite at automatica 2025. *“Our vision is to develop automation solutions that are so user-friendly and intuitive that they significantly simplify our customers’ work across an ever-growing range of applications”*, says Reinhold Gross, CEO of KUKA’s Robotics division.

The innovations that KUKA will be presenting in the Munich exhibition halls from 24 to 27 June pay tribute to this: an operating system including software packages and control hardware for the entire robotics portfolio, a digitalized and self-explanatory purchasing process, AI-supported programming, mobile platforms as well as software and hardware products for the automation of intralogistics, automotive with a focus on e-mobility, battery & electronics.

KUKA rolls out new operating system across entire portfolio

The new KUKA robot operating system iiQKA.OS2 , the associated engineering suite iiQWorks and the new KR C5 controller for iiQKA.OS2 will be the focus at automatica 2025. iiQKA.OS2 combines the best of two worlds – the proven core of the KUKA System Software (KSS) and the modern user interface with modular safety – and thus meets important automation requirements.

The new operating system will initially be available for small robots in 2025 and will then be gradually rolled out to the entire robot portfolio. At KUKA, it is not only the software portfolio that is growing, but also the hardware range: New to the portfolio is the KR TITAN ultra, which will be presented for the first time at automatica with a payload capacity of up to 1500 kg.

Artificial intelligence and software: KUKA digitizes the industry

KUKA is pursuing two goals with the use of artificial intelligence (AI): To automate internal processes and to incorporate AI into innovations in a meaningful way. In Munich, the automation company is demonstrating how AI can simplify the programming of robots in the future. Here too, the aim is to make access to automation as easy as possible for customers.

Digital products and services for intelligently networked, future-proof production are becoming increasingly important. In addition to robot-related software products that focus on the optimum performance of KUKA robots, hardware-independent offerings are required for the end-to-end digitalization of the industry. KUKA Digital takes care of this. The digital segment was founded in 2024 and unites the software specialists mosaixx, Visual Components and Device Insight, which will also be present at automatica 2025.

KUKA Group is the top dog of automation in Munich’s halls

Anyone walking through the halls at automatica will not be able to avoid the KUKA Group: Swisslog presents SynQ , the future-proof software that can be seamlessly integrated into warehouse systems, in the ‘KUKA Dome’ of KUKA’s system engineering division visitors can experience complete 3D system solutions in 360°, and KUKA robots can be found not only at KUKA’s main stand, but also at numerous partner stands showing which tasks can now be automated with the support of robots.

With mosaixx and Visual Components, two more companies from KUKA Digital will be represented in Munich. mosaixx will be celebrating the major product launch of its Software-as-a-Service platform of the same name at automatica 2025. Visual Components, the Finnish 3D manufacturing simulation and robot offline programming software provider, will be presenting version 5.0 of its platform during the show.

You will find:

- KUKA Group booth incl. KUKA Robotics, Swisslog, KUKA Digital and Device Insight in **Hall A4, Stand 231**.
- KUKA Dome in **Hall A4, Stand 435**.
- mosaixx booth incl. Autodesk, Daussault Systèmes, Visual Components and AWS in **Hall B5, Stand 510**.
- Visual Components stand in **Hall B5, booth 402**.

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UNIVERSAL ROBOTS INTRODUCES ITS FASTEST EVER COBOT

UNIVERSAL ROBOTS

For pick-and-place applications, the UR15 delivers up to 30% cycle time improvements compared to other UR models.

Universal Robots (UR) presented the newest addition to its portfolio, the UR15, at Automate in Detroit. The new cobot is available for orders now with shipping to begin in June.

With unparalleled motion capability and a maximum TCP speed of 5 m/s, UR15 is the fastest ever UR cobot, enabling reduced cycle times, increased productivity and reduced costs across applications and industries. For pick-and-place applications, the UR15 delivers up to 30% cycle time improvements compared to other UR models. All the while retaining the unique UR trademarks of lightweight design and small footprint to deliver unmatched flexibility for integration in tight workspaces.

Combined with OptiMove, UR's new motion control technology, those gains go even further, enhancing trajectory smoothness and ensuring consistently accurate movements - even in high-speed and high-payload applications.

Powered by PolyScope X, AI ready

UR15 runs with both PolyScope 5 and PolyScope X, UR's industry-leading software platform, and is ready to be supercharged with AI to enable unmatched usability. The UR15 can easily be used with the UR AI Accelerator, UR's toolkit for developing AI-powered applications. The UR AI Accelerator is developed in collaboration with NVIDIA using NVIDIA Isaac's™ CUDA-accelerated libraries and models and running on the NVIDIA Jetson AGX Orin™ system-on-module.

At the Automate show this week, 3D Infotech will demonstrate a turnkey quality inspection process with the UR15 and UR AI Accelerator demonstrating the potential of physical AI in the UR15.

Designed for flexibility, efficiency and reliability

The UR15 has a payload of 15 kg (33 lbs) which can be increased to 17.5 kg (38.58 lbs) for applications with wrist-down orientation, such as palletizing. UR15 is a versatile cobot designed to empower multiple applications and industries - each with their own unique challenges where flexibility, efficiency and reliability are critical.

Three of these industries are:

- Automotive, where space is tight, and flexibility is key. Here UR15's small footprint and full work envelope delivers performance without compromising space or speed. Common automotive applications historically limited by the production speed of cobots - such as automated bin picking, machine tending and inspection - can now be significantly sped up while retaining the highest level of precision.

- Metal and machining, where environments can be harsh. The UR15 offers improved ingress protection, IP65, and high payload capability - combined with easy deployment.

- Electronics and tech, requiring precision and compact design. With cleanroom class excellence, compact form and exceptional motion control, UR15 is ready for high-speed pick and place and smooth integration with AMRs and AGVs.

A cobot for every need

UR15 joins the UR20 and UR30 in UR's new high-performance series, the UR Series, designed for those who need higher payloads, advanced capabilities and certifications for demanding environments.

In addition to UR7e and UR12e, the e-Series also consists of UR3e and UR16e.

UR15 is available for orders now with shipping to begin in June. UR7e and UR12e are ready for immediate delivery.

www.universal-robots.com

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TEZMAKSAN'S CUBEBOX TOOL-PRO REVOLUTIONIZES CNC AUTOMATION FOR INDUSTRY 5.0

TEZMAKSAN Tezmaksan's CubeBOX Tool-PRO ATC system enhances CNC efficiency by 50%, reduces costs by 20%, and supports retrofitting for SMEs transitioning to Industry 5.0.

Gaining competitiveness is a priority for manufacturers and users of machine tools in Europe. This goal goes hand in hand with embracing digitalisation and achieving Industry 5.0. Automatic tool changers (ATC) play a role in this. Enabled by robotics, ATC can help OEMs develop more competitive machine tools that address end users' most pressing challenges. Here, Serhat Volkan Yilmaz, robot technologies general manager of Tezmaksan Robot Technologies, explains.

According to CECIMO, the European Association of Manufacturing Technologies, machine tool orders decreased by 20 per cent in the first quarter of 2024 compared to the same period last year. The association also estimates that consumption levels will be down 1.8 per cent by the end of 2024, with machine tool production falling by five per cent.

To become more competitive, machine tools must meet the end users' growing demand for efficiency, productivity and accuracy. This is where addressing labour-intensive operations, like machine tending, with automation can be a game changer.

Maximising competitiveness with easy-to-implement robotics

Routine machine tending operations like loading and unloading CNC machines remain predominantly manual across many manufacturing applications. This outdated approach can harm productivity and efficiency while also translating into high labour costs. Manual operations may also lead to human errors like improper tool placement or damage, impacting part quality and leading to unnecessary waste. The outcome is reduced competitiveness.

The most advanced ATC systems implement robotics into existing machine tools and prioritise intuitiveness. Visual elements, drag-and-drop functionality and predefined templates allow workers without programming skills to program robots to perform routine CNC operations with minimal training.

Modern ATCs like the CubeBOX Tool-PRO system from Tezmaksan enable multiple machines to operate seamlessly without interruptions caused by manual loading and unloading. This uninterrupted workflow translates to up to 50 per cent improvement in night shift efficiency compared with manual CNC machine tending, as proven by tests conducted by Tezmaksan. With this technology, OEMs can develop machine tools that enable end users to achieve greater productivity and shorter lead times.

Retrofitting is key to competitiveness

Embracing automation is a no brainer. However, it is often beyond the reach of many European machine tool OEMs and end users. For small-to-medium enterprises (SMEs) with limited financial resources, implementing complex automation systems entails significant overheads. One solution is retrofitting existing machines with intelligent capabilities thanks to hardware-agnostic ATC solutions.

Machine tool manufacturers can augment their existing product lines' capabilities without redesigning them. End users can enable the smart operation of legacy machines, extending their functional lifespan and delaying the need for costly replacements.

ATC systems like CubeBOX Tool-PRO maximise flexibility as they are compatible with all CNC machines and control units and can be adapted to all brands of robots. What's more, the system is 20 per cent cheaper than company-specific robot integration systems due to the plug-and-play nature of the solution.

Maximising competitiveness en route to Industry 5.0

Digitalisation is one of the core principles underpinning Industry 5.0. Leading machine tool producers like Italy are adopting specific legislation to incentivise OEMs and end users to digitalise their operations. The goal of these incentives is to help businesses maximise efficiency and gain competitiveness internationally. Real-time monitoring is critical to achieving this goal.

The integration of IoT-enabled ATCs in a smart factory environment already enables users to monitor machine tool operations in real time. For example, monitoring the energy consumption of multiple components within the system enables operators to implement corrective measures to optimise energy efficiency. Another core application of digitalisation is maintenance. Modern ATCs already enable operators to perform predictive maintenance. Advancements in AI will unlock huge opportunities for even more sophisticated predictive maintenance in the machine tool sector. Digital twinning is a case in point.

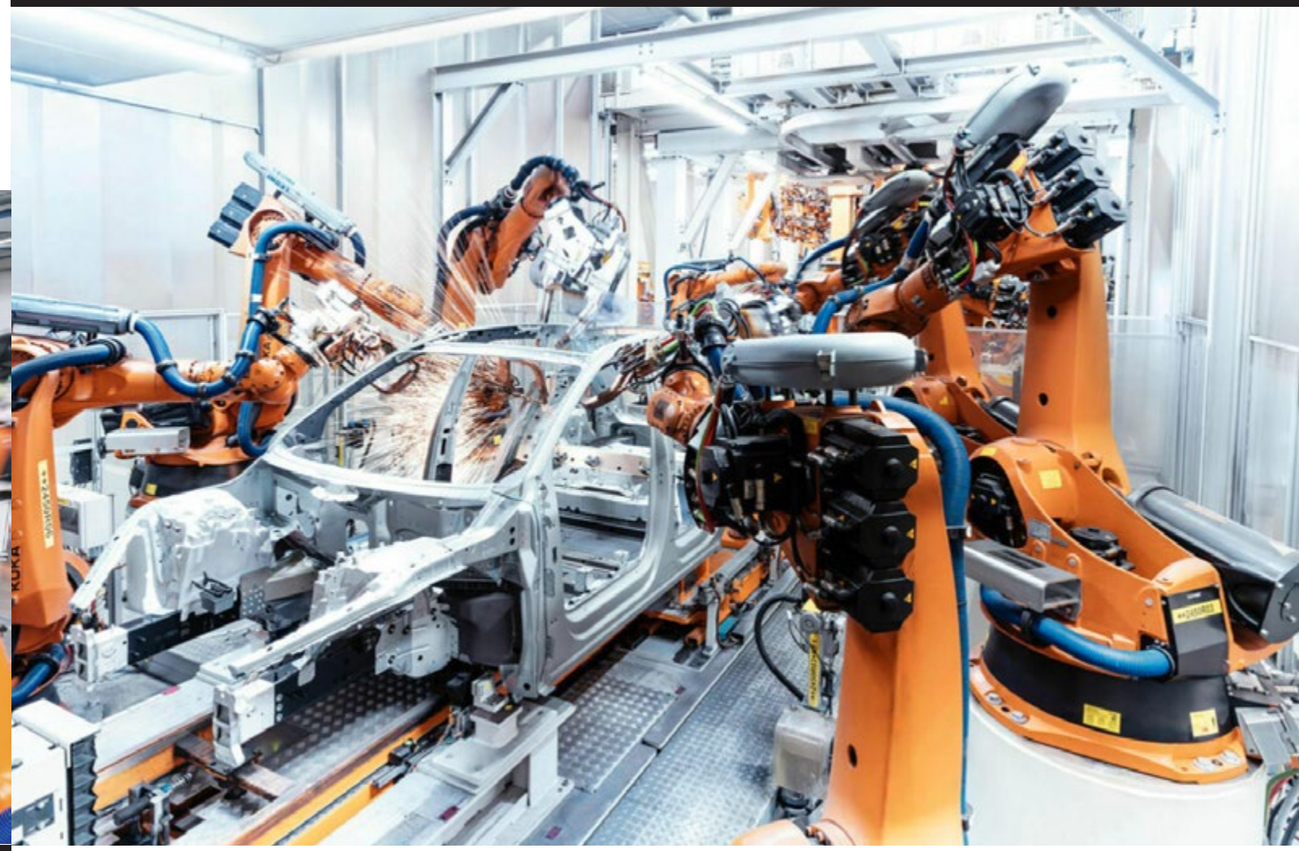
By creating a digital twin of an ATC system, maintenance engineers can perform critical predictive maintenance operations from remote locations while providing a range of after-sales services, from troubleshooting to spare part management and online monitoring.

The ability to prevent most faults and fix problems immediately will dramatically reduce downtime in machine tool applications. This is a win-win situation for machine tool manufacturers and end users. The former can gain competitiveness thanks to better machine products that meet their customers' needs. The latter can maximise efficiency and productivity, reduce costs and make progress toward Industry 5.0.

For more information about Tezmaksan's CubeBOX CNC automation system.

www.tezmaksan.com

SUSTAINABLE AND FLEXIBLE: PRODUCTION OF THE AUDI Q6 E-TRON SERIES IN INGOLSTADT



Since late 2023, Audi builds the fully electric Q6 e-tron in Ingolstadt—net-zero, with integrated production, battery assembly, and following the 360factory strategy.

Audi CEO Gernot Döllner emphasizes the significance of the first model based on the Premium Platform Electric (PPE): *"The PPE, and with it the Q6 e-tron series, form the basis for subsequent electric Audi models. In this way, we are taking a decisive step towards offering an electric model in all core segments in the medium term."* Audi Board Member for Production and Logistics Gerd Walker considers the start of production in late 2023 as an important milestone for the 360factory production strategy: "By the end of the decade, we will have successively equipped all Audi locations for electric mobility. We are harnessing electrification to comprehensively transform our existing plants. With the production of the Q6 e-tron series, the Ingolstadt plant is taking the next step towards becoming a 360factory." Audi has a clear vision for the production of the future.

As part of this holistic, sustainable approach, the company is modernizing, digitalizing, and transforming its existing plants. The Audi Q6 e-tron series, as well as all other vehicles built at the site, have been made with net zero emissions1 since 2024.

State-of-the-art production technology in the new battery assembly facility

One example of how Audi is modernizing and expanding its existing systems is the new battery assembly facility for PPE models. On an area of around 30,000 square meters (323,000 sq ft), 300 employees work in three shifts with an automation rate of almost 90 percent to assemble up to 1,000 high-voltage batteries per day for PPE-based models. "*In this way, we are increasing our vertical range of manufacture while also bringing additional skills and technologies to the location,*" explains Board Member for Production and Logistics Walker.

The new facility, which is located in a dedicated battery assembly hall at the Logistics and Goods Transport Center (GVZ) in Ingolstadt, is powered exclusively by green electricity. This also allows Audi to achieve even greater flexibility and efficiency in production without sealing additional areas for new buildings.

Electric motors for PPE from the world's largest powertrain plant in Győr

Ingolstadt is sourcing the electric motors for the new Premium Platform Electric (PPE) technology platform from the world's largest powertrain plant in Győr, Hungary. Audi Hungaria manufactures electric motors for the PPE on three newly installed production lines. The motors are then transported to Ingolstadt by the transportation and logistics company DB Cargo with zero emissions. Audi has been producing at the Győr site with net zero emissions1 since 2020. "*Sustainable production in existing plants is the core of our 360factory manufacturing strategy and an integral step on our path towards building a future-proof production network,*" says Walker.

Retooling and a flexible equipment concept in the body shop

In order to make production of the Q6 e-tron series sustainable and efficient at the same time, Audi has integrated production domains such as the body shop for the PPE into existing structures. The bodies for the PPE models are assembled at the Ingolstadt plant on an area of around 148,000 square meters (1.6 million sq ft). There, 328 employees per shift and 1,150 robots build the body components for the Q6 e-tron series with an automation rate of 87 percent.

The highly flexible equipment will also enable the virtually seamless launch of future models. In order to make sustainable and synergistic use of resources, Audi is reusing more than 600 machines such as robots that were already used to produce other Audi models in the body shop for the production of PPE bodies. Audi is also putting a new fleet of more than 40 automated guided vehicles (AGVs) into operation for the Q6 e-tron series. The AGVs supply materials in the hall and also supply the body shop with the required parts in automated operation.

Assembly of PPE models with existing equipment

Audi consistently relies on existing systems and equipment for assembly. For example, the Audi Q6 e-tron series was seamlessly integrated into the assembly line previously used for the Audi A4 and A5 models. It took Audi eight stages of modification to integrate the PPE models into its assembly operations.

Higher automation in the paint shop

Production has also extended the paint shop for the new fully electric series. Among other changes, the dryer after the cathodic dip coating (CDC) process step was extended and a new integrated procedure for automatically sealing holes was introduced. After CDC, robots use adhesive pads to seal about 70 holes in the bodies, each of which is measured individually for this step. Previously, employees had to manually perform this part of the process. Audi upgraded the dryer to meet the higher energy requirements for curing the bodies after CDC. This modification ensures all parts of the body reach the target temperature of 160 °C (320 °F) required for curing the CDC. The Ingolstadt paint shop also uses automated production technology that helps detect, evaluate, and process surface irregularities. This makes it possible to objectively inspect finished surfaces, increasing

MORE INFORMATION

process reliability and making quality monitoring more transparent. In the first step, robots scan the vehicle surfaces using an automated measuring system. This process is the basis for finishing, which is also an automated process. Each finishing robot is equipped with a grinding and polishing tool. In the subsequent step, employees inspect the processed areas on large screens.

Flexible equipment concept for hot forming

At the press shop in Münchsmünster, a team of experts has been working hard to upgrade the hot-forming process for the PPE. Hot forming is primarily used to produce safety-related components: This process gives extra stability and crash safety to sheet metal parts for the body structure of vehicles on the PPE, such as A- and B-pillars, as well as parts of the longitudinal members. After being heated to around 950 °C (1,742 °F) in a special furnace, sheets of metal are formed into the desired component in a forming press using the appropriate template. By locally cooling the heated metal using air vents, Audi can influence the strength of the components as needed to further optimize crash performance while reducing the weight of the body.

Due to the high hardness of the material, it is then necessary to use special lasers to cut the desired contours into the components.

In addition to components for models based on the PPE, the production equipment is also being used to produce components for combustion-engine models based on the PPC (Premium Platform Combustion). This new level of flexibility means the equipment can be used to manufacture a total of 44 components in Münchsmünster. Changing the setup of the laser cells and forming presses is fully automated and time-optimized, resulting in a plant output of around 20,000 individual parts per working day.

Much more information about the world premiere of the Audi Q6 e-tron model series can be found in the Audi MediaCenter.

(1) Audi understands net-zero CO2 emissions to mean a situation in which, after other possible reduction measures have been exhausted, the company offsets the carbon emitted by Audi's products or activities and/or the carbon emissions that currently cannot be avoided in the supply chain, manufacturing, and recycling of Audi vehicles through voluntary offsetting projects carried out worldwide. In this context, carbon emissions generated during a vehicle's utilization stage, i.e. from the moment it is delivered to the customer, are not taken into account.

www.audi.com

MORE INFORMATION

GEEKPLUS DEBUTS WORLD'S FIRST MULTI-TEMPERATURE PALLET AUTOMATION SYSTEM

World's first multi-temperature pallet-to-person system enables seamless frozen-to-chilled warehouse automation with frost-resistant robots, high-speed lifts, and smart software.

Geekplus, the global leader in warehouse robotics, has launched the world's first pallet-to-person system designed to automate warehouse operations across frozen and chilled zones, setting a new benchmark for temperature-controlled logistics.

Now live at a 2,700 sqm flagship facility operated by leading cold chain logistics provider JJCL (Jinjiang Cold Logistics), the system enables seamless pallet movement between environments ranging from -18°C to +5°C. This marks the first production-grade deployment of fully automated multi-temperature pallet handling in the industry.

While automation has transformed much of logistics, cold storage facilities have lagged behind due to extreme conditions and technical barriers. Geekplus' SkyCube system changes that with frost-resistant engineering and a coordinated fleet of high-density pallet storage robots operating at -18°C, P800 robots in chilled zones (0–5°C), high-speed lifts, and a unified software platform built for continuous operation in sub-zero environments.

"*Cold chain logistics is no longer the exception to automation. It's the next frontier,*" said Liu Kai, Head of System at Geekplus. "*Our systems are built to perform where other systems fail. With our multi-temp-compatible robotics, we're redefining how food, pharma, and grocery warehouses scale reliably and efficiently.*"

JJCL, with seven subsidiary branches and 11 cold storage facilities totaling over 560,000 m^3 (approximately 20 million cubic feet), partnered with Geekplus to modernize operations and meet growing demand. Since deployment, the system has increased storage capacity by 70 percent, improved picking efficiency by 90 percent, and achieved 99.99 percent accuracy. It has also enhanced safety by minimizing human exposure to extreme sub-zero temperatures through full automation of cold zone handling.

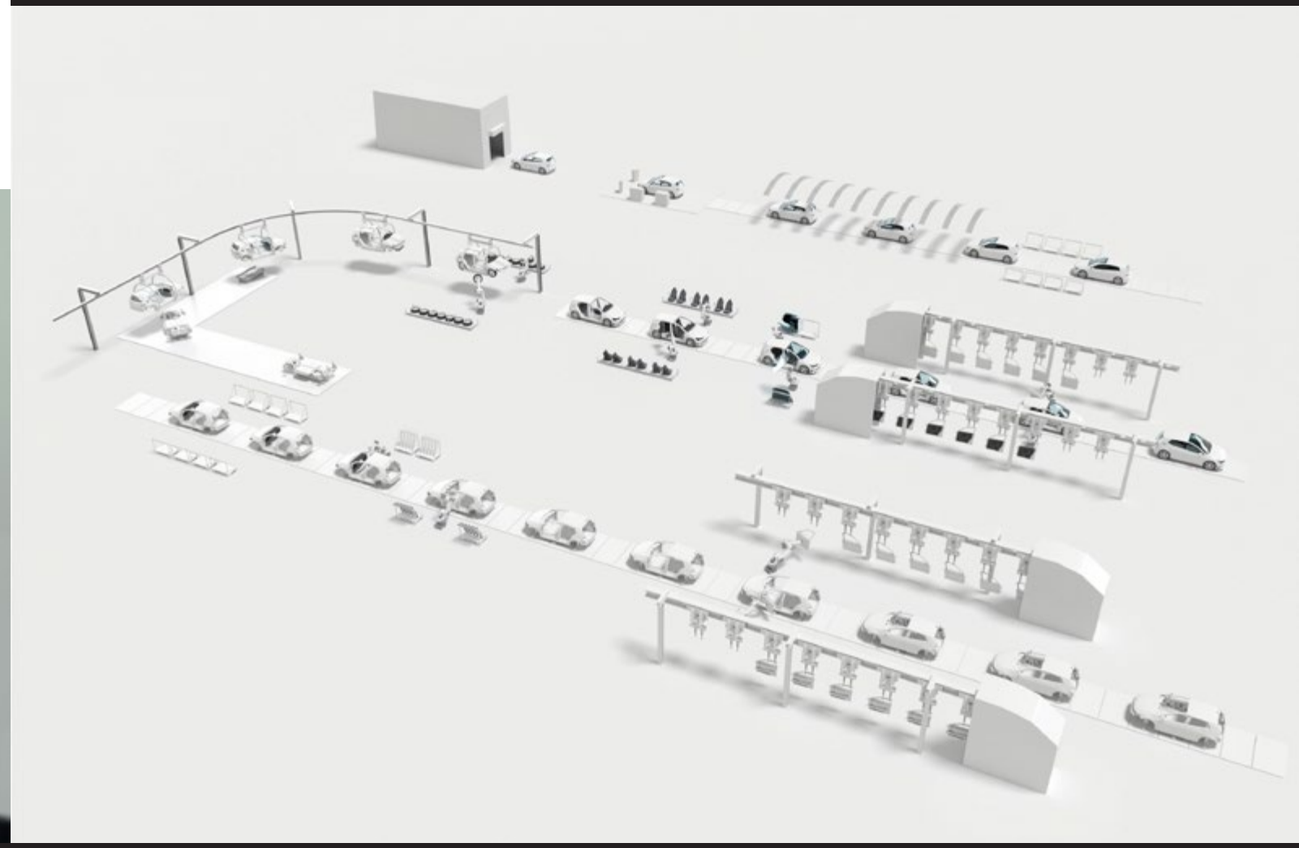
"*As global demand for cold chain services accelerates, the launch provides a scalable blueprint for 3PLs, food distributors, and pharma companies navigating compliance, labor challenges, and operational risk,*" Liu added. "*This isn't just an upgrade, it's a category shift.*"

www.geekplus.com

MORE INFORMATION

LEUZE SMARTID-EDGE: REAL-TIME OBJECT AND PROCESS TRANSPARENCY AT FIELD LEVEL

Leuze SmartID-Edge offers maximum object and process data transparency thanks to intelligent, secure identification at edge level.



Networking plays a crucial role in production and logistics automation systems. This can be designed efficiently, transparently and securely with the SmartID-Edge concept from Leuze

SmartID-Edge enables intelligent identification, linking barcodes with virtual RFID tags to ensure secure, real-time data access at the edge.

Leuze SmartID-Edge controls a network of identification systems and sensors for track-and-trace requirements in production and the supply chain. Secure communication between 1D scanners or 2D camera systems takes place at edge level using OPC UA and full integration of the AutoID Companion Specification.

The advantage: Each object to be identified is not only represented by its code, but also mapped on a virtual tag in the edge system. Further process, status and sensor information can then be assigned to the virtual tag. This data is available in real time across all processes. Data exchange is even synchronized across network boundaries. This means that all information for continuous process tracking is instantly available at field level. This relieves the burden on higher-level IT systems such as MES.

Digitization and networking are central topics of our time. In the industrial environment, they shape concepts such as Industry 4.0 and the Industrial Internet of Things (IIoT). Networking plays a particularly crucial role in today's automation systems in production and logistics. The goal here is to be able to call up the production processes' exact status at any time and to keep a complete overview of the production-relevant data at field level. This involves key questions such as: How can users efficiently achieve maximum transparency in their production processes? And how secure is the communication between the network participants?

Multiple requirements for efficient identification

Modern automation systems in production or intralogistics have a number of control systems, sensors and actuators. These are networked with each other via Ethernet-based communication or fieldbus systems and can exchange data. Sensors generate event-based signals to activate production processes or provide measurement values to monitor correct production processes and quality requirements. AutoID systems such as 2D camera systems and RFID readers identify objects, load carriers and containers in production and in the material flow.

Modern identification systems typically need to be able to handle variable amounts of data and different code systems, depending on the object to be identified. With classic 1D/2D codes, however, these possibilities are limited because standardized bar codes such as a Global Trade Item Number (GTIN) only provide a defined, unchangeable and rather small amount of data. Furthermore, a bar code always requires access to a higher-level IT system such as MES or ERP, where the complete data record that the bar code represents is stored. RFID benefits from the flexibility of the data carriers ('tags') used, in addition to the physical principle's other advantages. These usually have a freely programmable electronic memory – this means that product and process data required for specific situations can be stored directly on the object. For economic or technical reasons, however, it is not always practical or possible to use RFID. Frequent changes of media from bar code to RFID are also undesirable in continuous production processes because they result in increased effort in automation processes and data handling.

SmartID-Edge: Using data more intelligently

This is where the SmartID-Edge concept from Leuze comes in. It uses standardized RFID mechanisms to process and store identification data while retaining the classic optical bar code technology. This is achieved by linking RFID data structures and command sets with standard bar code scanners and camera-based scanners using OPC UA as the data exchange standard and a fully integrated AutoID Companion specification. Each physical bar code is assigned a virtual RFID tag, which is stored in a database on an edge server. Data is exchanged at field level exclusively between the bar code devices and the edge server. The system's control system, for example a PLC, has no access to the edge server – the PLC can only access the bar code identification systems, although these behave like RFID systems.

This opens up unprecedented possibilities for enriching data when identifying objects in the production process: In addition to the unique object ID, status information about the identification system as well as reading quality and other process and status data can be stored in a data record. This data record can be accessed directly in real time at field level. Queries to MES and ERP systems are no longer necessary, which relieves data traffic in the networks and frees up system resources at the IT level. Multiple local sensor and AutoID networks can be synchronized via distributed

MORE INFORMATION

The SmartID-Edge solution from Leuze offers several integrated security mechanisms, including integrated end-to-end encryption via OPC UA.

Camera-based code readers using SmartID-Edge not only provide individual object identification, but also device and status information for each production step

edge servers. This means that all identification events are available throughout the network at all times. Linking these local events with the associated information stored in the edge database over the entire production lifecycle thus provides the basis for the digital twin. This can even be achieved within a supply chain with different suppliers and plants by expanding the edge server with an API and cloud connection. This allows logistics to work more efficiently, eliminates manual data entry and avoids complex system transitions in business software (ERP).

Maximum security

Measures for secure communication are essential for trouble-free, smooth use of networked systems. Here, the SmartID-Edge solution offers several integrated security mechanisms. Modern automation components and identification systems with communication via Ethernet-based interfaces or fieldbuses such as ProfiNet, Ethernet/IP or EtherCAT have integrated web servers. The web servers allow convenient access to the devices in the local network. To meet the high requirements for adaptability, precision and performance, any necessary updates to the device firmware must be fast, reliable and secure. Recognized functional improvements can thus be implemented without replacing the device and new functions can be implemented automatically. At the same time, it must be ensured that only authorized firmware is loaded into the device and that the data transfer cannot be manipulated. These requirements for secure data transmission are becoming fundamental cornerstones of modern automation systems that communicate locally in networks and via cloud systems, not least due to the EU's Cyber Resilience Act.

OPC UA provides an interoperable, Ethernet-based communication platform that features integrated end-to-end encryption. In addition, the OPC UA Device Interface Specification Part 100 defines a vendor-independent procedure for performing and managing software updates. The direct loading procedure is recommended for devices with limited hardware resources. The new software is transferred as a file archive, whereby each file is checked by its specific header and installed immediately after unzipping. After a final check, the device is restarted. All communication via OPC UA and thus also the software download are secured by exchanging certificates between client and server. Automated certificate exchange via an external Global Discovery Server (GDS) ensures central management of applications and certificates in the entire OPC UA network. Communication between the network participants therefore meets the highest security requirements: Data cannot be manipulated. This ensures that each device is always operated with the latest and, above all, exclusively original firmware.

Summary

SmartID-Edge offers a powerful platform for networking identification systems at field level. The special concept of data handling using edge servers and virtual data carriers offers maximum transparency in track-and-trace applications as well as efficient access to object and process data at every point in the supply chain in real time. It also meets the high requirements for cyber resilience thanks to its integrated security mechanisms.

www.leuze.com

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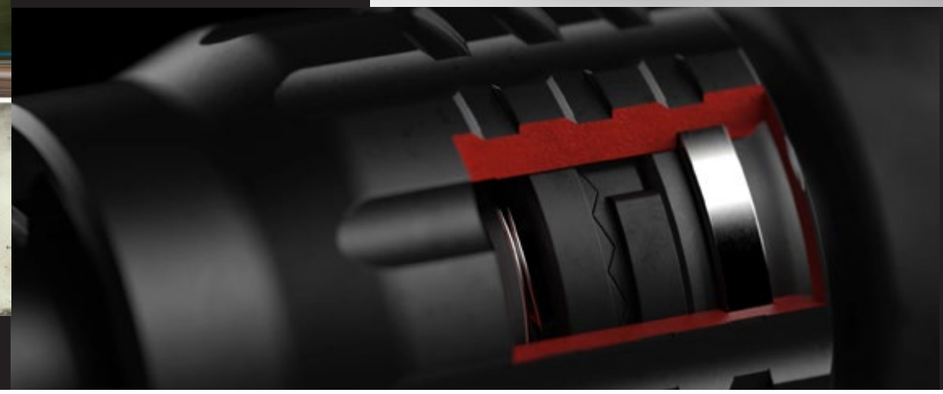
FISCHER ULTIMATE SERIES ADDS USB-C WITH RATCHET LOCK FOR MAXIMUM DURABILITY

The Fischer UltiMate™ USB-C RLS connector is available as pre-cabled plugs and receptacles.



The RLS fastening mechanism uses an asymmetrical tooth profile to securely lock under load and resist loosening under high vibration.

The Fischer UltiMate™ USB-C connector featuring the Ratchet Locking System (RLS) is ideal for high vibration applications such as armored vehicles, UAVs, UGVs, railways, and motorsports.

The newly released Fischer UltiMate USB-C connector with the Ratchet Locking System (RLS) combines high-speed data transmission with the robust mechanical performance Fischer Connectors is known for.

Fischer Connectors adds a rugged USB-C with Ratchet Locking System to its UltiMate™ Series, delivering secure, high-speed data transfer in extreme conditions across industries like defense, mining, and motorsports. The newly released Fischer UltiMate USB-C connector with the Ratchet Locking System (RLS) combines high-speed data transmission with the robust mechanical performance Fischer Connectors is known for.

Leveraging its core competencies in ruggedization, sealing, miniaturization, and data transmission, Fischer Connectors designed the connector to provide optimal reliability in mission-critical environments, ensuring safe and stable connections in demanding applications and markets, such as defense armored vehicles, UAVs, and UGVs, mining, heavy machinery at construction sites, motorsports, and railways. These environments are characterized by high levels of vibration and shock.

Ratchet Locking System (RLS) designed to resist high vibration and shock

At the heart of this innovation is the new Ratchet Locking System (RLS). Its fastening mechanism uses an asymmetrical tooth profile to securely lock under load and resist loosening under high vibration. Key benefits include exceptional vibration resistance (by maintaining lock under high-frequency vibration), tool-free operation (easy mating and unmating in the field, even with gloves), and durability with high rates of mating cycles.

Logically, Fischer Connectors has introduced the RLS to its most robust product line, UltiMate. In the Fischer UltiMate's classical size 15 contact block (with up to 27 pins and 25.8-mm receptacle diameter), the RLS system achieves the best vibration and shock resistance in the entire Fischer Connectors product portfolio, withstanding 37.8 Grms of random vibration and 300 g of shock amplitude.

Ruggedized USB-C connector for harsh environments

The new UltiMate USB-C connector with RLS has been independently validated to withstand 5.35 Grms of random vibration (50–2000 Hz, 3x1.5 hrs, no discontinuity >1 µs), 10 g of sinus vibration (10–500 Hz, 3x3 hrs, no discontinuity >1 µs), and shock up to 100 g (half sine pulse, 6 ms, no discontinuity >1 µs).

Additional features include an IP68 sealing for the plug; hermeticity for the receptacle (<10 ^{8} mbar l/s); an operating temperature range of -30 °C to +80 °C; corrosion resistance of 350 hours of salt mist; 3,000 mating cycles; and 360° EMC shielding.

"*Our new USB-C RLS connector offers environmental and mechanical performance in compliance with IEC and MIL-STD norms,*" says Alexandra Monchâtre, Head of Product Management at Fischer Connectors. "*This new product truly offers the best of both worlds: the ultra-standard and the ultra-rugged.*"

As part of a versatile portfolio of rugged, compact and high-speed connectors

With its new USB-C interface supporting high-speed data, video, and power transmission over a compact connector footprint, the new Fischer UltiMate USB-C RLS connector complements Fischer Connectors' existing range of rugged, high-speed data transmission solutions designed for signal integrity, mechanical endurance, and space-constrained environments.

The UltiMate USB-C RLS is available as a pre-cabled plug and receptacle (28 mm diameter) with a flex PCB. This all-in-one solution provides robust connectivity and flexibility in various design configurations for modern electronic devices, especially in applications where space, speed, and reliability are critical. It offers a compact design and supports USB 3.2 Gen 1x2 transmission with data rates up to 10 Gbit/s.

The new USB-C RLS connector expands Fischer Connectors' offerings across its high-speed Core, MiniMax, and UltiMate series, which support data protocols such as USB 3.2, Ethernet up to 10 Gbit/s, Audio/UHD Video up to 18 Gbit/s (HDMI 2.0 type), and Single Pair Ethernet (SPE).

"*As part of our technology and innovation strategy, our Group R&D team offers engineers designing applications in extreme environments a versatile technology platform with various standards and connector types,*" explains Alvaro Goncalves, Technology Director at the Conextivity Group, of which Fischer Connectors is a part. "*This new USB-C connector with RLS is a good example of how we combine our technology 'bricks' – high-density miniaturization, high-speed data, and ruggedness – to increase integration capability, compatibility, and interoperability across customer markets. Conextivity has the innovation, agility, and precision skills needed to meet the most stringent requirements in demanding environments.*"

www.fischerconnectors.com

RIGOL TECHNOLOGIES DEBUTS HIGH-PERFORMANCE OSCILLOSCOPES AT EFY EXPO 2025

MHO2000 Series Oscilloscope

RIGOL

Featuring new MHO2000 and DS80000 Series designed for power, automotive, and high-speed electronics.

RIGOL Technologies, a global leader in electronic measurement instruments, proudly announces the launch of two powerful additions to its oscilloscope portfolio: the MHO2000 Series and the DS80000 Series. These next-generation instruments will be showcased for the first time in India at EFY Expo 2025, taking place from May 15–17 at the Auto Cluster Exhibition Centre, Hall 2, Booth B1, Pune.

These solutions are tailored to meet the growing challenges of power electronics, automotive systems, high-speed digital designs, and medical electronics, combining high-resolution signal capture, intelligent analysis, and integrated features—all in compact, user-friendly packages.

MHO2000 Series – Multi-functional, High-Resolution Oscilloscope
The MHO2000 Series is a cost-effective, high-resolution mixed-signal oscilloscope offering up to 350 MHz bandwidth, a 12-bit ADC, and real-time sampling rates up to 2 GSa/s. It integrates protocol analysis, logic analysis, and signal generation into one compact unit—making it ideal for power, medical, and automotiveapplications.

With 500 Mpts of memory depth, digital input channels (supporting mixed-signal debugging), and vertical sensitivity as low as 200 µV/div, the MHO2000 provides engineers with precision waveform visibility. A built- in dual-channel signal generator (16-bit, up to 50 MHz) adds further testing versatility.

DS80000 Series – High-Bandwidth Flagship for High-Speed Design
Built on RIGOL's advanced StationMAX® II platform, the DS80000 Series is designed for high-speed, high-precision measurements with up to 13 GHz analog bandwidth and a real-time sampling rate of 40 GSa/s. It offers 4 Gpts/channel memory depth, ensuring deep waveform capture and detailed signal analysis.

The oscilloscope supports Smart Probe 2.0, allowing compatibility with both modern and legacy differential/ probe setups, and is optimized for compliance testing (USB3.0, MIPI D-PHY, automotive Ethernet) and signal integrity validation in applications like semiconductors, RF systems, FPGAs, and optical communication.

See It Live at EFY Expo 2025
Visitors to EFY Expo can experience both products firsthand, speak with RIGOL engineers, and explore application demos.

Location: Hall 2, Booth B1 — Auto Cluster Exhibition Centre, Pune
Dates: May 15–17, 2025

https://in.rigol.com/

DS80000 Oscilloscope

MORE INFORMATION

THE IXXAT CAN/FD REPEATER STANDARD

HMS Networks launches the Ixxat CAN/FD Repeater Standard, offering a compact solution for optimized topology, improved signal quality, and equipment protection in CAN networks.

HMS Networks has introduced the new CAN/FD Repeater Standard under its product brand Ixxat. As a crucial component for network infrastructures, the device solves several complex market challenges such as topology optimization, signal quality improvement, seamless integration in existing CAN networks, equipment protection by galvanic isolation and many more. The Ixxat CAN/FD Repeater Standard delivers an all-in-one solution for industrial communication. Easy to access, easy to understand and easy to use.

The CAN/FD Repeater from Ixxat is tailored to meet the needs of system integrators and plant engineers around the world, offering unmatched performance, ease of use and sustainability in one compact product. Designed to address diverse use cases with cost-efficiency, it is a true price-performance champion.

Easy does it: Unmatched Handling and Integration Advantages

The termination resistors are easily adjustable from the outside via piano switches. This means that users don't have to open the housing for adjustment and the current switching status can easily be seen from outside. This feature simplifies installation and maintenance, saving valuable time.

The repeater additionally features push-in connectors for CAN/FD connections, drastically reducing maintenance efforts. This innovation enables a secure, tool-free connection for a seamless setup and operation. With it, connecting the device to the CAN lines can be done within seconds. Another feature is the built-in cable tie hole, that offers a practical solution for tidy installations, further simplifying cabinet organization. "*The CAN/FD Repeater Standard provides many useful integration and handling features, that are scarcely available on the market combined in one product*", explains Frank Iwanitz, Product Manager at HMS Networks. "*With two CAN/FD channels it fulfills the most commonly needed CAN functionalities and on top unites several useability benefits at a competitive pricing.*"

The CAN/FD Repeater Standard comes with a slim and compact housing, optimized for DIN-rail mounting, fits perfectly into control cabinets with limited space. Clear labeling and intuitive LED indicators make operation straightforward, even for first-time users.

EMI Protection and Easy Termination

The new Repeater provides a 5 kV galvanic isolation between CAN channels and the power supply, ensuring robust protection and system reliability, even in challenging industrial environments. "*By using repeaters in CAN networks, connected equipment can be protected very easily*", says Product Manager Iwanitz. "*It's not only about the optimization of your network topology or optimizing your signal quality but about increasing and protecting the health of your whole CAN network. That's a huge advantage users benefit from!*"

Performant and Sustainable at the Same Time

Aligned with HMS Networks' commitment to sustainability, the Ixxat CAN/FD Repeater Standard comes in eco-friendly packaging and does away with printed manuals, offering digital resources instead. It also debuts HMS Networks' new modern design, marking a fresh era for Ixxat products. "*With our new cardboard packaging, we're heavily reducing packaging costs*", says Iwanitz. "*Additionally omitting the printed manuals is not only a consequence of the market feedback we received, but also a logical consequence of the HMS sustainability policy.*"

The CAN/FD Repeater Standard is available on stock as of now at a list price of 222 Euro.

Key Technical Features

- Two CAN/CAN FD interfaces supporting arbitration rates up to 1 Mbit/s and data rates up to 8 Mbit/s
- CAN/FD Transceiver TCAN1044
- CAN connection: Removable Push-In Connectors
- Externally Switchable CAN bus termination resistors
- Galvanic Isolation up to 5 kV
- Operating Temperature -25 °C to +70 °C
- Protection Class IP20
- Dimensions 108 x 149 x 27 mm
- Power-efficient design operating at less than 100 mA at 24 V DC
- Compliance with CE and FCC certifications

www.hms-networks.com

ALTECH RELEASES ALSENSE ENERGY MONITOR FOR ADVANCED INDUSTRIAL ENERGY MANAGEMENT

The Alsense Energy Monitor delivers exceptional accuracy with voltage measurements precise to ≤0.15% and current measurements accurate to ≤0.25%.

Altech Corp.

Altech Corporation, a leader in industrial automation solutions, announces the release of its Alsense Energy Monitor (AMR-ES3M480V5A2M), a high-precision monitoring system that provides industrial facilities with real-time energy data to optimize energy usage, reduce costs and enhance sustainability initiatives.

The Alsense Energy Monitor supports both 1-phase and 3-phase systems with voltages up to 277 VAC (L - N)/ 480 VAC (L - L), delivering exceptional accuracy with voltage measurements precise to ≤0.15% and current measurements accurate to ≤0.25%. This compact DIN rail device provides comprehensive energy monitoring capabilities, including voltage measurement, current measurement, active and reactive power tracking and power factor analysis.

Built for industrial environments, the Alsense operates reliably in temperatures from -25°C to +40°C and features vibration and shock resistance. With Modbus RTU/ RS485 communication capabilities, it integrates seamlessly with existing SCADA systems and data logging platforms.

The Alsense joins Altech's monitoring solutions portfolio, which includes its Voltage Protection Relay, Current Monitoring Relays and Voltage Monitoring Relay. These products provide a complete energy monitoring ecosystem that enhances efficiency, reduces costs and protects valuable equipment.

www.altechcorp.com

MORE INFORMATION

OMRON INTRODUCES NEW AUTONOMOUS MOBILE ROBOT SOLUTION FOR MATERIAL HANDLING

OMRON

The OL-450S is built to streamline material transport with a 450 kg payload capacity, adjustable lift height, advanced navigation, and wireless charging.

OMRON has released the OL-450S, a low-profile, omnidirectional autonomous mobile robot (AMR) designed to optimize workflows, maximize efficiency, and improve safety in material handling.

Featuring an integrated lifting plate, advanced navigation, and centralized fleet management, the OL-450S offers a complete solution for automating material transport in automotive, semiconductor and electronics, food and household goods, medical, and other fast-paced industries.

Streamlined and safe material handling
The OL-450S efficiently handles the transport of roll cages, trolleys, and other load carriers with a payload capacity of up to 450kg and a lifting height range from 108 to 308mm. Its integrated lifting plate eliminates the need for customization or toppers, providing a plug-and-play solution compatible with both standard and custom racks. This allows businesses to improve operational efficiency without infrastructure changes.

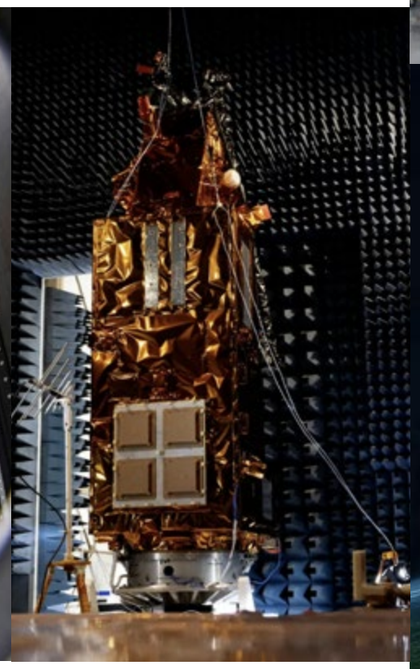
Advanced navigation and wireless charging for smarter operations
Equipped with 360-degree safety coverage and omni-directional drive, the OL-450S navigates complex layouts with ease, avoiding obstacles and ensuring safe operation around personnel. Strategically positioned sensors and 360-degree safety coverage enhance localization, while its flexible movement—including forward, reverse, and lateral—allows it to adapt to evolving operational demands. With wireless charging, the OL-450S offers flexible deployment, simplified management, and uninterrupted workflows.

Centralized fleet management for maximum efficiency
As with all OMRON AMRs, the OL-450S is managed by OMRON's FLOW Core software, a centralized platform capable of managing fleets of up to 100 mobile robots with varying payload capacities. This enterprise-level system ensures seamless integration into existing infrastructure, enabling streamlined operations and optimal fleet performance.

https://youtu.be/V7CLV2Gzbbc
www.industrial.omron.eu

MORE INFORMATION

AIRBUS BUILT FOREST MONITORING SATELLITE BIOMASS SUCCESSFULLY LAUNCHED



AIRBUS

Airbus' Biomass satellite successfully launched to monitor global forests, using P-band radar to enhance climate and carbon cycle understanding.

The Airbus built forest monitoring satellite Biomass has been successfully launched into orbit. A European Space Agency (ESA) flagship mission, Biomass will use its revolutionary P-band synthetic aperture radar instrument to measure forest biomass to assess terrestrial carbon stocks and fluxes to enable scientists to better understand the carbon cycle and its effects on climate change.

Launched on a Vega-C rocket from Europe's Space Port, Kourou, French Guiana, the satellite will scan the Earth's forests from an altitude of 666km during its five-year mission.

"*Biomass will give scientists and climatologists unprecedented data on the state of the world's forests, further enhancing the understanding of the climate cycle. The spacecraft is now safely in orbit and ready to deliver its precious data,*" said Alain Fauré, Head of Space Systems at Airbus Defence and Space.

An ESA Earth Explorer mission, Biomass carries the first space-borne P-band radar, to deliver exceptionally accurate maps of tropical, temperate and boreal forest biomass to help improve the understanding of the part that forests play in regulating climate.

Biomass will also be able to measure paleo aquifers in desert regions to find new water sources in arid regions as well as contribute to observations of ice sheet dynamics, subsurface geology and forest topography. Biomass' P-band radar will see through the forest canopy to the ground, improving current Digital Elevation Models in densely forested areas and provide a completely new view of the Earth's surface.

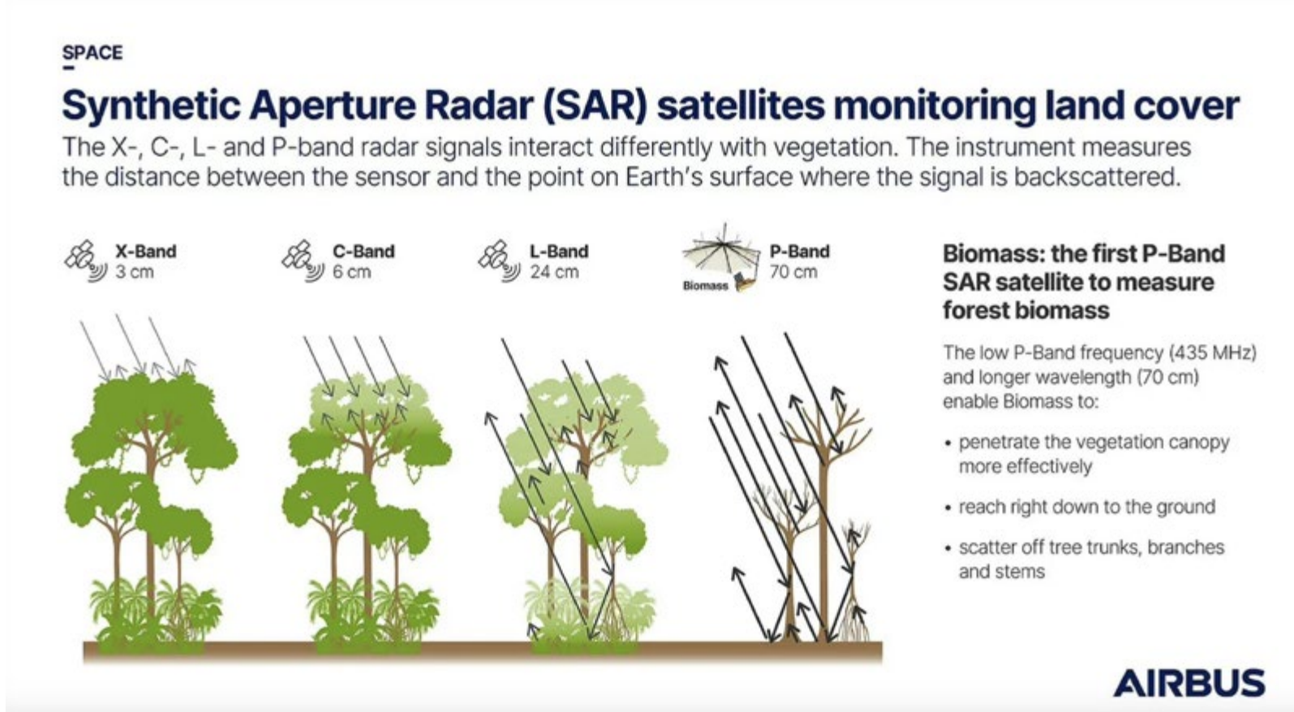
The spacecraft features a large 12 metre deployable antenna to capture the reflected SAR data to show changes in biomass due to forest loss (for example from logging/burning) and regrowth. Airbus developed, built and tested the satellite in Stevenage (UK) Friedrichshafen (Germany) and Toulouse (France) before it was shipped to French Guiana in February 2025. The teams are preparing for the in-orbit commissioning and operational phases, with a separate team managing the delivery of the ground calibration transponder, located in New Norcia, Australia.

Development and testing of the Biomass spacecraft involved more than 50 companies across 20 countries.

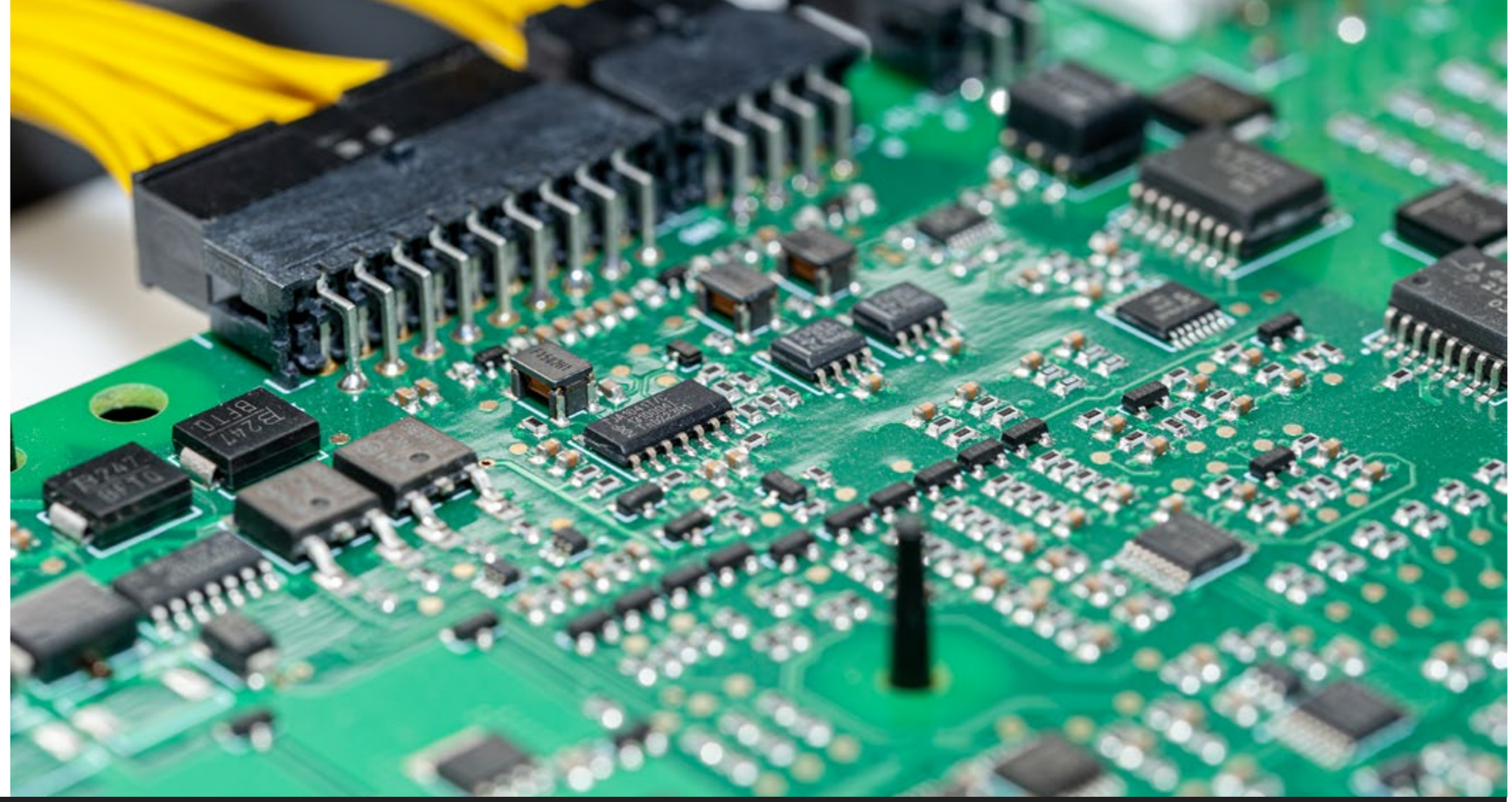
Biomass data will support REDD+, a UN climate change initiative aimed at reducing emissions due to deforestation, by systematically monitoring forests in vulnerable areas with no need for ground intervention.

www.airbus.com

MORE INFORMATION



FPT INDUSTRIAL'S EBM 5 BMS TECHNOLOGY ACHIEVES TOP INDUSTRY CERTIFICATION, ENHANCING CUSTOMER SAFETY



FPT Industrial's eBM 5 Battery Management System for high voltage batteries received ISO 26262 ASIL C certification.

This result highlights the qualities of the fifth-generation battery management system, designed and developed entirely in-house by the integrated FPT Industrial and Potenza Technology team, from the circuitry right through to the software base and application layers. This state-of-the-art system is defined by flexibility and scalability. With a highly modular design at its core, it is compatible with 400- or 800-volt battery systems, which can be configured at an application level to optimize vehicle efficiency and performance. This enables OEMs to maximize the system's effectiveness for each use case, right across the mobility spectrum – from commercial vehicles through to hypercars – including multi-pack management (which is not in scope of the certification) without an additional controller. The eBM 5 is currently in volume production for the IVECO eDaily MY24, as well as for numerous other customers.

Pierpaolo Biffali, Vice President Product Engineering at FPT Industrial, commented: "*This is an important step forwards in consolidating our electrification roadmap to accelerate decarbonization of the commercial vehicles segment. Each technological innovation we make always translates into tangible value for our customers, and the eBM 5 represents a solid way to ensure the efficient and safe operation of their battery electric vehicles.*"

Neeta Khare, Battery and Fuel Cell Director at FPT Industrial, commented: "*Throughout the development phase, the team was driven by the principle of making our product robust, reliable, and safe. As a result, we implemented significant improvements across various areas, including processes, testing infrastructure, design documentation, and traceability – from requirements to testing. This enhanced approach has led to the TÜV SÜD ASIL C certification and has also further strengthened our confidence in the reliability and safety of our BMS product.*"

Richard Devenport, General Manager & Head of Battery Development at Potenza Technology, an FPT Industrial brand, stated: "*This is a true achievement that has been years in the making. The goal was always to produce an OEM standard Battery Management System suitable for a wide range of vehicles. While other BMS suppliers often use the 'self-certification' process, where their work products are reviewed within their own company to confirm compliance to the standard, we aimed to have ours assessed by an external body, to guarantee a level of quality and completeness that few others can boast. We backed up that claim by going the extra mile to obtain certification from TÜV SÜD, one of the world's leading experts on functional safety and a founding participant in the establishment of the ISO 26262 standard.*"

ISO 26262 is an international standard for functional safety in the automotive industry, applied to electrical and electronic systems that consist of hardware and software components in vehicles. This standard defines the requirements for both the safety-relevant functions of the system and the development process, ensuring that an adequate level of safety is maintained throughout the vehicle lifecycle. The standard is based on ASIL (Automotive Safety Integrity Level), a risk classification system that analyzes potential hazards by considering the severity, frequency, and controllability of the vehicle's operational scenarios.

eBM 5 – Technical Specifications

- High Voltage range: 400 V and 800 V systems
- Low Voltage range: 6 to 32 V
- Operating Temperature (C°): -40 to 85
- Software - Multipack Support: Yes (not in scope of the certification)
- ASIL System: ASIL C
- Algorithm (SOX): inbuilt

Complete specifications are available on FPT Industrial's website.

www.fptindustrial.com

MORE INFORMATION

MORE INFORMATION

ICONICS INTRODUCES GENESIS: A PARADIGM SHIFT IN SCADA AUTOMATION & DIGITALIZATION SOFTWARE

GENESIS is a next-generation SCADA automation and digitalization platform engineered for unmatched scalability, flexibility, and intelligence.

ICONICS has redefined the future of industrial automation software with the launch of GENESIS. Built from the ground up with the user in mind, this bold breakthrough software is designed to meet the evolving demands of today's industrial automation applications.

GENESIS is a next-generation SCADA automation and digitalization platform engineered for unmatched scalability, flexibility, and intelligence. This new platform (also referred to as GENESIS version 11) leverages ICONICS' decades of software development expertise while breaking away from traditional models, embracing an innovative architecture that will empower organizations to transform and optimize their operations now and in the future.

Revolutionizing SCADA Automation & Digitalization with Next-Generation Capabilities

GENESIS propels industrial automation and digital transformation forward with these groundbreaking features:

- Unlimited licensing, and scalability to handle any system size.
- Advanced visualization, comprehensive alarm management, and enhanced system control.
- Data-centric architecture featuring an embedded industrial-strength historian and robust security.
- Universal connectivity and native integration with an expanded set of Mitsubishi Electric devices.
- Rapid deployment, future-proof support, and full extensibility.
- Asset modeling with unified namespace (UNS) and adherence to industry standards.

The Next Chapter in SCADA Automation & Digitalization

ICONICS has taken bold steps to ensure that GENESIS is the future of industrial automation. Organizations can now streamline their design and deployment processes to implement a wide range of digitalization project solutions faster and more efficiently than ever before.

This vision is echoed by Kyle Reissner, ICONICS Vice President, Product Management, "*We're redefining the SCADA and digital transformation software landscape with GENESIS version 11. This software has been completely reimagined, purpose-built for the evolving needs of industrial automation. With its data-centric architecture, cutting-edge features, and unlimited licensing, this software marks a major industry leap.*" He adds, "*Customers will be blown away by the game-changing components inside GENESIS and the unlimited licensing model, which includes a data historian, reporting, clients, and more.*"

Whether it's enterprise-wide intelligent control, operational awareness, or enterprise analytics, GENESIS redefines what's possible in SCADA automation and digitalization software.

More on GENESIS version 11

Learn all about this revolutionary software on our GENESIS webpage

www.iconics.com

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