AUTOMATION IN MANUFACTURING

The impact on industry and workforce

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INTRODUCTION

The rapid evolution of automation in advanced manufacturing is reshaping the manufacturing landscape, driving unprecedented technological advancements and significantly influencing labour markets worldwide. As industries strive to enhance efficiency, precision, and productivity, the integration of solutions such as robotics, artificial intelligence (AI), and the Industrial Internet of Things (IIoT) are supporting the evolution of manufacturing to new levels of autonomy, connectivity, and performance.

However, the rise of automation also presents significant challenges and opportunities for the workforce. As machines and AI systems increasingly take on roles traditionally performed by humans, there is a growing need for workers to adapt to new skillsets and job functions. Therefore, the shift towards automation in manufacturing necessitates a re-evaluation of educational and training programmes to ensure the workforce is equipped with the new required skills.

We are currently at the beginning of the curve of integrating automation technology in manufacturing, necessitating a strategic industry-wide approach to better incorporate innovative advanced technologies into manufacturing process. By analysing the intricate benefits and barriers of automation and workforce dynamics, this report aims to inform policymakers, industry leaders, and educators about the importance of focusing on the development of automation solutions and its impact on the advanced manufacturing sector.

THE BENEFITS OF AUTOMATION FOR THE MANUFACTURING SECTOR

Automation offers significant benefits for the manufacturing sector as it streamlines operations, reduces production costs, and minimises human error, positioning European companies at the forefront of innovation and global market leadership.

By facilitating stronger human-machine collaboration, automation allows workers to focus on more complex, creative tasks while advanced robotics handle repetitive or hazardous duties. This shift not only boosts productivity but also ensures higher quality and reliability in production, as machines deliver consistent results with fewer defects. Furthermore, automation brings greater flexibility to manufacturing processes, enabling quick adaptation to market demands and technological advancements. It also strengthens workplace security by reducing human error and minimizing risks associated with dangerous tasks. Finally, automation contributes to enhanced sustainability, optimising resource use and reducing environmental impact through precise control and efficient operations.

Benefits of automation in manufacturing:

1. Improved quality and reliability

Automation ensures consistency in production, which benefits the overall product quality and enhances the process reliability. Automated quality control systems continuously monitor and inspect products during manufacturing, immediately identifying and correcting deviations. This real-time feedback loop catches defects early, reducing waste and enhancing product quality.

With precise and repeatable procedures, automated systems consistently deliver products that meet high-quality standards. This not only improves customer satisfaction but also strengthens companies' reputation for reliability and excellence.

2. Higher flexibility

Automation significantly enhances flexibility, allowing systems to adapt rapidly to varying production demands and the introduction of new elements. This greater control over automated processes means manufacturers can easily scale up production volumes in response to market demands or integrate new product lines without substantial downtime and without extensive reconfiguration. This flexibility not only improves efficiency but also enables manufacturers to respond swiftly to changing consumer preferences and technological advancements, helping them maintain a competitive edge in the market.[1]

3. Stronger security

Automation minimises the need for human intervention, thereby reducing the risk of accidents and errors. Automated systems are programmed to follow strict safety protocols consistently, eliminating the variability and potential for human error. These systems can continuously monitor for potential hazards and swiftly react to any anomalies, such as machine malfunctions or environmental changes, with a level of precision and speed that surpasses human capabilities. Furthermore, automation reduces the need for workers to perform dangerous tasks, significantly decreasing the likelihood of workplace injuries. Overall, the integration of automated technologies in manufacturing not only ensures a safer working environment but also enhances compliance with industry safety standards, leading to a more reliable and secure production process.[2]

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[1] ElMaraghy, H.A., 2005. Flexible and reconfigurable manufacturing systems paradigms. International Journal of Flexible Manufacturing Systems. Available at: https://doi.org/10.1007/s10696-006-9028-7.
[2] Mueller, T., Kiesel, R., and Schmitt, R.H. (2020) 'Automated and Predictive Risk Assessment in Modern Manufacturing Based on Machine Learning'. Available at: https://link.springer.com/chapter/10.1007/978-3-030-43345-3_12

4. Enhanced sustainability

Automation in manufacturing significantly enhances sustainability by increasing resource efficiency and reducing emissions through precise control mechanisms. This precision minimises waste, optimizes process planning and scheduling, and lowers energy consumption, resulting in a reduced carbon footprint.[3] Automated systems are particularly effective at recycling and reusing materials, diminishing the need for new resources and mitigating environmental impact. With real-time monitoring, automated processes ensure compliance with environmental regulations and enables immediate process adjustments to minimise environmental harm. Additionally, these systems reduce energy usage by operating only when necessary and adjusting operations to off-peak energy rates.

5. Stronger human-machine collaboration

Automation promotes effective human-machine collaboration by enhancing workers' cognitive and creative abilities rather than replacing them. Advanced robotics, including collaborative robots (cobots), allow humans to engage in more intellectually stimulating tasks while cobots handle repetitive or hazardous duties, improving overall worker safety. By working alongside humans, cobots reduce the risk of accidents and streamline data collection, leading to quicker safety issue resolution. [4]

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[3] Jamwal, A., Agrawal, R., Sharma, M. & Giallanza, A., (2021). Industry 4.0 Technologies for Manufacturing Sustainability: A Systematic Review and Future Research Directions. Available at: https://doi.org/10.3390/app11125725.

[4] Matheson, E., Minto, R., Zampieri, E.G.G., Faccio, M. and Rosati, G., (2019). Human–Robot Collaboration in Manufacturing Applications: A Review. Available at: https://doi.org/10.3390/robotics8040100

CHALLENGES TO AUTOMATION ADOPTION

The adoption of automation in manufacturing presents several common initial barriers that can impede its implementation. These include fear of change, difficulty in identifying eligible areas for automation and high upfront costs. These barriers collectively hinder the seamless integration of automation technologies, despite their potential to revolutionise manufacturing efficiency and productivity.

Challenges in Integrating Automation:

1. Data management and analytics

The integration of automation solutions generates vast amounts of data from sensors, machines, and processes. Managing this data and transforming it into actionable insights is a significant technical challenge. Implementing data management and analytics solutions involves setting up robust data infrastructure, including storage, processing, and analysis capabilities. Additionally, leveraging technologies such as machine learning and AI to analyse data in real time and make predictive decisions requires sophisticated algorithms and substantial computational power. Therefore, developing these capabilities and integrating them into existing manufacturing operations is a complex and resource-intensive task.

2. Technical expertise

Integrating industrial automation solutions into manufacturing processes demands a high level of technical expertise. The transition from manual or semi-automated systems to fully automated operations require in-depth knowledge of various technologies (e.g. IIoT). Engineers and technicians must be trained to understand the intricacies of these technologies and how they interact within the broader manufacturing environment. This includes, for example, designing and implementing custom interfaces to ensure seamless communication and interoperability between legacy systems and new automated equipment. Therefore, acquiring and developing this expertise within a company often requires significant investment in training and hiring, making the integration of industrial automation solutions a complex and resource-intensive undertaking.

3. System integration and interoperability

Manufacturing environments often consist of a diverse array of machines, devices, and software, many of which were not originally designed to work together. Achieving seamless communication and data exchange between these different systems requires the development of bespoke interfaces, middleware solutions, and possibly the adoption of standardised communication protocols. Therefore, ensuring that new automation solutions can effectively integrate with existing infrastructure without causing disruptions is a complex and technically demanding task.[5]
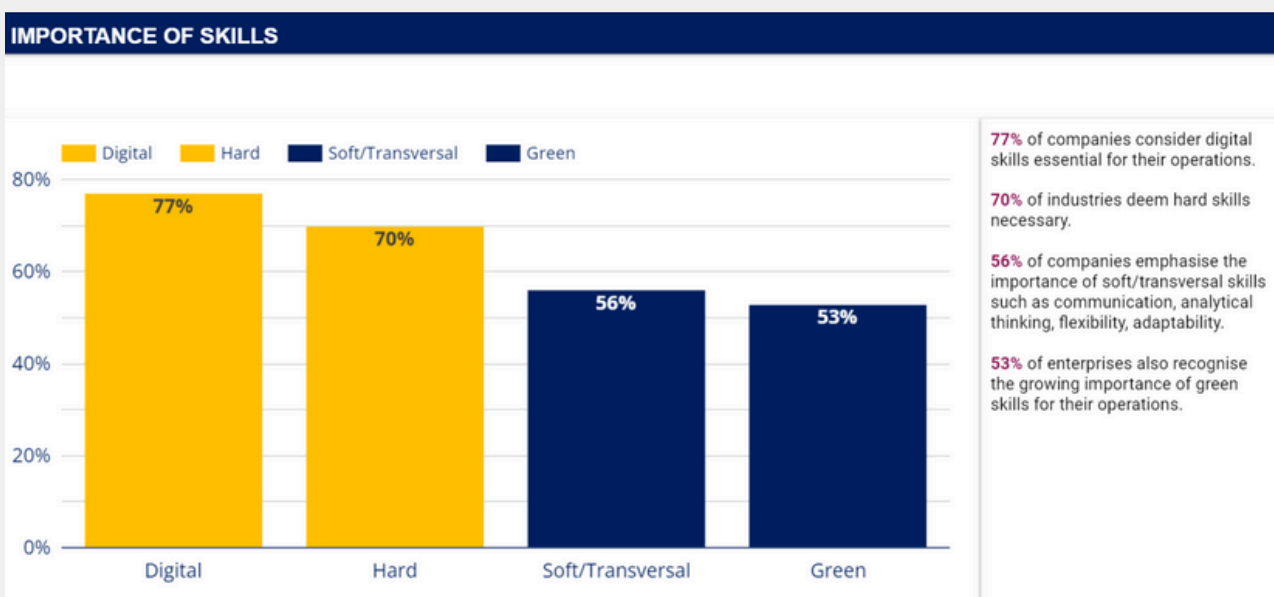
4. Cybersecurity vulnerabilities

With the increasing connectivity of industrial automation systems through IIoT, cybersecurity becomes a critical concern for all companies. Automated manufacturing systems are prime targets for cyber-attacks, which can lead to production downtime, data breaches, and compromised intellectual property. Implementing robust cybersecurity measures requires a comprehensive approach that includes secure network architecture, regular software updates, continuous monitoring, and employee training on cybersecurity best practices. For this reason, developing and maintaining these security protocols to protect against ever-evolving threats presents a significant technical challenge for manufacturing companies.[6]

[5] Zeid, A., Sundaram, S., Moghaddam, M., Kamarthi, S., and Marion, T., 2019. Interoperability in Smart Manufacturing: Research Challenges. Machines. Available at: https://doi.org/10.3390/machines7020021

[6] O'Connell, T., Chatzigeorgiou, D., and Bhattacharya, R., 2023. Digital Twins as Enablers of Interoperability in Smart Manufacturing. International Journal of Advanced Manufacturing Technology. Available at: https://link.springer.com/article/10.1007/s00170-023-12345

SKILLS TO MATCH FUTURE INDUSTRY NEEDS

The World Economic Forum (WEF) predicts that the accelerated adoption of automation and the redefined division of labour between humans and machines will disrupt many jobs in the manufacturing sector, potentially slowing job creation. While not all jobs will be fully automated, a significant portion may face displacement, particularly affecting middle-skill workers in roles like sales, office administration, production, craft, and repair. This shift could lead to a polarisation in employment, with growth in high-education, high-wage jobs and low-education, further exacerbating income inequality[7].

Positive correlation between automation and employment

Automation transforms human work through three primary mechanisms: substitution, complementarity, and new task creation. As Industry 4.0 advances, integrating automation and AI, the emphasis remains on the human element. According to the World Economic Forum, machines handle 34% of business-related tasks, while humans manage the remaining 66%[8]. Over the next two decades, industries will likely face a shortage of workers, making robotics and automation crucial for filling these gaps. CECIMO's report[9] on skills *"From survey to strategy: understanding skills trends in advanced manufacturing"* highlights the growing importance of digital skills and robotics in manufacturing, indicates that professional roles will require more advanced skills[10]. In addition, automation not only replaces hazardous manual tasks with robots but also creates safer jobs, improves working conditions, increases productivity, and complements human skills. Automation has the merit to eliminate much undesirable work and simultaneously boosting productivity and elevating working standards.

IMPORTANCE OF SKILLS

Legend: Digital | Hard | Soft/Transversal | Green

- Digital: 77%
- Hard: 70%
- Soft/Transversal: 56%
- Green: 53%

77% of companies consider digital skills essential for their operations.

70% of industries deem hard skills necessary.

56% of companies emphasise the importance of soft/transversal skills such as communication, analytical thinking, flexibility, adaptability.

53% of enterprises also recognise the growing importance of green skills for their operations.

Source: https://www.cecimo.eu/skills-dashboard

On the topic of the reallocation of tasks for the least qualified workers when implementing automation, a common misconception is that automation leads to widespread job losses. However, companies laying off employees solely because they introduced automation into their production processes are not widespread among the industry. Instead of eliminating jobs, automation often transforms them. Tasks that were once manual and repetitive can be automated, allowing workers to focus on more complex and value-added activities. Companies typically reassign employees to roles that require human skills such as problem-solving, oversight, and maintenance of automated systems. This shift can lead to upskilling opportunities for the workforce, fostering a more versatile and capable team. Thus, rather than being a threat to employment, automation can serve as a catalyst for job evolution and growth within a company.

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[7] MIT Work of the Future Task Force, The Work of the Future: Shaping Technology and Institutions, Fall 2019 Report.
[8] World Economic Forum, Future of Jobs Report 2023, Insight Report 2023.
[9] From survey to strategy: understanding skills trends in advanced manufacturing, Olha Hunchak, CECIMO, 20 March 2024.
[10] David Autor, David A. Mindell, and Elisabeth B. Reynolds, MIT Technology Review, The work of the future, Building better jobs in an age of intelligent machines, 2021.

Emergence of New and Higher-Level Jobs: Redefining the Human Element

Automation can create new, highly qualified, and technical roles that didn't exist before its integration. It can also address labour shortages by stabilising production in regions with limited labour availability, ensuring continued growth despite a shrinking workforce. However, human involvement remains critical for industry success. An integrated approach that combines human strengths with automated systems yields the best results. Providing upskilling opportunities and involving employees in automation implementation fosters a supportive company culture, mitigating resistance to change.

Automation and digitisation enhance the appeal of the manufacturing sector by nurturing desirable skills, changing the type of jobs created, and increasing worker satisfaction. Traditionally associated with manual labour, the industry has struggled to attract young talent. Advanced technologies are now making manufacturing more attractive to a new generation of workers.

While automation may initially displace some positions, it generates numerous job opportunities in the long run. The impact of automation on employment involves both replacement and compensation effects, ultimately fostering a complementary relationship between humans and machines. As automation technology evolves, demand for highly skilled labour to work alongside automated systems will grow. This demand will span fields such as automation research and design, equipment manufacturing, and application. For instance, every ten large intelligent robots may require one AI engineer, with smaller robots necessitating even more engineers[11].

Adapting the workforce to meet the evolving demands of automation is crucial. Automation frees employees to focus on higher-value tasks but also requires ongoing training and skill development. The skills gap in operating and maintaining automation systems presents a significant challenge. As automation technology progresses, the impact on low-skilled labour becomes more pronounced. However, alongside technical expertise, soft skills like analytical thinking, creativity, and flexibility are increasingly valued.

Retraining and reskilling programmes are essential to help displaced workers transition to new opportunities. Despite the expense and inflexibility of robots, companies are investing in automation to address challenges in recruiting and retaining workers. it is important to recognise that not all automation leads to job displacement; collaborative robots/cobots, for example, are designed to work alongside humans, enhancing productivity.

Evolution of Skills and Jobs

As automation technologies advance, the range of tasks they can undertake broadens, encompassing both simple, repetitive manual tasks and moderately complex mental tasks such as programming and software development. This evolution impacts the workforce on both the Original Equipment Manufacturer (OEM) and end-user sides, with distinct variations. On the OEM side, there's a growing need for training Service Engineers in equipment and software to enhance production processes. Meanwhile, on the end-user side, there's a rising demand for training Maintenance Engineers in equipment and software. Overall, to fully embrace automation solutions in manufacturing companies, training is required for professional profiles such as Operators, Maintenance Engineers, Application Engineers and consulting services.

However, such training should not only focus on theoretical knowledge but also on skills gained through on-the-job training, apprenticeships and practical experience. Additionally, social interactions with managers and colleagues for coaching, mentoring and constructive feedback are crucial. This includes the social aspects of training such as attitude and behaviour, which translate into essential soft skills. For example, the GF Academy uses the 70:20:10 model for training. According to this model, 70% of training is focused on applying learning on-the-job, 20% on social training such as coaching, mentoring, and 10% on formal training through courses and programmes.

[11] Jiang H, Ge Y, Yang C, Yu H. How automated machines influence employment in manufacturing enterprises? PLoS One. 2024.

Employees in advanced manufacturing will need a combination of technical and soft skills as highlighted in the CECIMO skills report[12]. Some of the main technical skills will include:

- **Robotics and Automation**: Understanding the operation, programming, servicing and maintenance of robotic systems.
- **CNC Machining:** Operating and programming CNC machines.
- **Mechatronics**: Integrating mechanical, electronic, and software engineering to control automated systems.
- **CAD/CAM Software**: Designing and modelling parts using Computer-Aided Design and Computer-Aided Manufacturing Software.

Essential human-centric skills include:

- **Communication**: Conveying technical information clearly.
- **Analytical Thinking**: Analysing problems, identifying root causes, and implementing effective solutions.
- **Adaptability and Learning Agility**: Staying updated with the latest technological advancements and adapting to new roles and responsibilities as technology evolves.

In conclusion, a balanced focus on both technical and soft skills is essential in an environment that offers versatile training combining practical experience and formal learning. Continuous learning and flexibility will empower workers to better adapt to an automated industry, ensuring they remain valuable assets in a dynamic job market.

[12] From survey to strategy: Understanding skills trends in advanced manufacturing, Olha Hunchak, CECIMO, 20 March 2024.

THE EU SUPPORT FOR AUTOMATION IN MANUFACTURING

The EU has been actively supporting and promoting automation in manufacturing through its funding programmes and policies. This support is part of a broader effort to enhance the competitiveness and sustainability of the European manufacturing sector. Key aspects of the EU's approach include:

Programme/Initiative	Support for Automation
Digital Europe Programme	Funding for projects related to high-performance computing, AI, cybersecurity, and advanced digital skills.
Horizon Europe	Funding for R&D in advanced manufacturing technologies like robotics, AI, and Industry 4.0 solutions.
European Innovation Council (EIC)	Grants and investments for start-ups and SMEs working on breakthrough technologies, including manufacturing automation.
Factories of the Future (FoF)	Public-private partnership aimed at improving the technological base of EU manufacturing.
European Digital Innovation Hubs (DIHs)	Assistance in improving business/production processes, products, or services using digital technologies.

Strategy/ Policy	Support for Automation
Industrial Strategy	Emphasizes digitalization and deployment of advanced manufacturing technologies
Green Deal and Circular Economy Action Plan	Automation and digital technologies as key enablers for reducing waste, improving resource efficiency, and sustainable manufacturing processes
Skills Agenda	Includes reskilling and upskilling initiatives for workforce adaptation to automated and digital manufacturing environments

The strategic adoption of automation not only strengthens the EU's industrial base but also fosters a robust, competitive edge in the international marketplace. By investing in automation technologies, the EU could overcome some of the current challenges, boost competitiveness and drive economic growth. This proactive approach positions the EU as a potential market leader in automation solutions for the manufacturing industry, setting a benchmark for innovation and efficiency worldwide.

RECOMMENDATIONS

As industries transition to a smarter future, the need for financial resources and a skilled manufacturing workforce, specialised for implementation, maintenance and programming, is critical. This shift underscores the importance of continuous learning and tailored training initiatives to prepare employees for evolving skill requirements. However, technology alone cannot create, innovate, or solve complex problems. Embracing Industry 4.0 requires a culture cantered around continuous learning, growth and financial support. Industry and competitiveness are likely to be more on the forefront of the next Framework Programme FP10 for research funding. Reports by Enrico Letta[13] and Mario Draghi highlight the importance of these topics and the competitiveness of our industries, emphasising the need to work closely with the industry in the next institutional mandate to address the automation challenges.

Recommendations for industry:

- **Promotion of Academic and Vocational training**: To address the shortage of automation engineers, industries should focus on both academic education and vocational training to build a skilled workforce with practical know-how.

- **Stakeholder Partnership for Skills Development**: Collaboration between stakeholders can prepare the workforce for Industry 4.0. Education and training programmes should be designed to equip individuals with the necessary skills needed for businesses, while companies should stay informed about available training opportunities from robot suppliers, training institutions, or third-party organisations.

- **Educating the End User**: Industry and policymakers must collaborate to educate end users about the possibilities of advanced manufacturing technologies. Clear and continuous communication is essential to inform businesses of all sizes about the benefits, accessibility, and potential of these technologies, thereby driving adoption and minimising misconceptions.

- **Encouraging Collaboration in Manufacturing Digitisation**: European Digital Innovation Hubs (EDIHs) are essential for assisting SMEs with digitisation. Engaging with EU-funded networks of digital innovation can offer companies valuable support, technical expertise, guidance, and access to financing and training opportunities.

- **Tailored Training Programmes**: Industries should work closely with automation providers to develop training programmes that provide employees with the technical skills they need to operate automation systems. Implementing work-based learning programmes like co-ops and apprenticeships, along with facilitating knowledge transfer through documentation and mentorship programmes, can cultivate continuous learning.

- **Reskilling and Upskilling**: Investing in reskilling and upskilling initiatives can help workers transition into roles that complement automated manufacturing processes. Training in areas like data analysis, robotics operation, CNC machining, maintenance etc. will be particularly valuable.

- **Reallocation of Tasks**: it's important to address job displacement by reallocating tasks for the lowest-qualified workers who are affected by automation, ensuring they continue to contribute meaningfully to the workforce.

[13] Letta, E. (2024) 'Report on the Future of the Single Market', European Commission and European Council. Available at: https://ecommerce-europe.eu/news-item/enrico-lettas-report-on-the-future-of-the-single-market/

Recommendations for policy makers

- **Investment in Automation Technology:** EU and national policymakers should support and recognise industrial automation as a critical component of modern manufacturing by integrating it into national and EU-level economic and educational frameworks. Policymakers should encourage investment in cutting-edge automation technologies through grants, subsidies, tax incentives and the inclusion of automation in the taxonomy with "premium" benefits for adoption. This includes establishing clear standards and guidelines for automation, offer incentives for businesses, and align workforce training programmes with the skills required for an increasingly automated industry.

- **Incentives for Digital and Green Investments:** Policymakers should introduce incentives for end users encouraging them to invest in digital and green technologies, promoting sustainable practices within manufacturing and supporting the EU's environmental goals.

- **Encouraging Risk Capital:** drive innovation, policymakers should create favourable conditions for risk capital investment that can support the development, scaling, and commercialisation of new automation and digital technologies.

- **Minimising Restrictive Export Sanctions:** Industry growth must not be hindered by restrictive export sanctions. Policymakers need to ensure that over-regulation, especially concerning dual-use technologies, does not hinder impede or limit the competitiveness of European companies in global markets.

- **Fair Trade and Market Surveillance:** It is critical for policymakers to implement robust market surveillance mechanisms to ensure fair trade practices and prevent the influx of non-conforming products into the EU market, thus protecting both consumers and European manufacturers.

- **Increased EU Funding:** The next European funding programme must increase the funding opportunities to address challenges in adopting and optimising automation solutions. Upskilling existing operators and maintenance engineers is highly important, and allocating funds for R&D and skills development is essential. Leveraging programms like Horizon Europe, Digital Europe, Erasmus+, EIC, and the European Regional Development Fund (ERDF) can help advance automation technologies and develop the necessary workforce skills.

- **Expanding and Leveraging EDIHs for Advanced Digital Manufacturing:** The European Commission should prioritize expanding the reach and capabilities of EDIHs by increasing funding and resources. Strengthening partnerships between EDIHs, industry, and academia will enhance their effectiveness in supporting SMEs.

- **Digital Infrastructure Investments:** Investments in digital infrastructure, such as high-speed internet, data centres, and cybersecurity, should be prioritised to support the widespread adoption of automation technologies across the EU.

- **Clear and Effective Regulatory Framework:** The European Commission should establish a clear and accessible regulatory framework that facilitates the adoption and full utilisation of advanced manufacturing technologies within the EU's manufacturing base.

- **Clear Communication to Counter Preconceived Ideas:** It is essential to address the misconception that automation eliminates jobs; instead, automation creates new roles with improved working conditions. It is important to communicate that automation is relevant for all types of production companies, not just mass production, and that programming and implementation are manageable and accessible for businesses of all sizes.

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About CECIMO:

CECIMO is the European Association of Manufacturing Technologies. With a primary focus on machine tools and additive manufacturing technologies, we bring together 15 national associations, which represent approximately 1500 industrial enterprises in Europe (EU + UK+ EFTA + Türkiye), over 80% of which are SMEs. CECIMO covers 97% of the total machine tool production in Europe and about 1/3 worldwide. It accounts for approximately 150,000 employees and a turnover of around 27.2 billion euros in 2023.

Austria: Metaltechnology Austria
Die MetalltechnischeIndustrie

Belgium: AGORIA
The Federation of Technology Industry

Czech Republic: SST
Svazu Strojírenské Technologie

Denmark: The Manufacturing Industry
a part of the Confederation of Danish Industry

Finland: Technology Industries of Finland

France: Evolis
Organisation professionnelle des biens d'équipement

Germany: VDW
Verein Deutscher Werkzeugmaschinenfabriken e.V.

Italy: UCIMU
Associazione dei costruttori Italiani di macchine utensili robot e automazione

Netherlands: FPT-VIMAG
FederatieProductieTechnologie / Sectie VIMAG

Portugal: AIMMAP
Associacão dos Industriais Metalúrgicos, Metalomecãnicos e Afins de Portugal

Spain: AFM Cluster
Asociación española de fabricantes de máquinas-herramienta, accesorios, componentes y herramientas

Sweden: MTAS
Machine and Tool Association of Sweden

Switzerland: SWISSMEM
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