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Humanoid Robotics 2040

Executive Summary

The dawn of humanoids – not a question of if, but of when and how

Humanoid robotics has evolved from a research-driven niche into a promising market at the center of a strategic global race. Expectations are skyrocketing: enthusiasts believe in trillion-dollar turnovers with billions of robots installed in 2040. Europe is exceptionally strong in both research and engineering talent with leading expertise in industries, smart hardware and innovative SMEs. In China and the United States, large investments, rapid iteration, and early deployments accelerate learnings and push capabilities forward in real-world environments. At the same time, structural pressures are intensifying across economies: labor shortages in services and industry, demographic change, rising expectations, for service quality and the need to improve safety and ergonomics in physically demanding work. Humanoids are increasingly discussed as a response to these challenges because they are built for a world designed for humans - able to navigate existing spaces, use tools, and perform diverse tasks without the need for full re-engineering of environments.

The European machinery and equipment industry is already very active in this in this interesting new potentially high-growth market: from component developers with embedded AI to robot manufacturers offering complete systems and platforms. Ultimately, all mechanical engineering companies represent a huge potential user base for humanoids in their own production processes. How ready are these systems for deployment—today and over the next 10 to 15 years? What are the tasks facing industry, research, and policymakers? What is the status of competitiveness and societal acceptance? In this tenth scenario study looking ahead to the year 2040, we outline the opportunities that humanoid robotics can offer for the future.

Clearly, the future of humanoid robotics does not follow a straight line. Developments in technologies, standards and regulation, market economics, and social acceptance interact in ways that can accelerate their future adoption or halt it quickly. Critical safety incidents, unclear liability, privacy concerns, or fragmented standards can trigger lasting setbacks in trust. At the same time, breakthroughs in energy systems, actuation technologies, dexterous manipulation, and "physical AI" can widen the range of tasks that become economically viable. In this context, there is no single forecast that would be credible. The relevant question therefore is not "will humanoids happen?" but in which different ways they could unfold and what role Europe's machine makers can play in this emerging field of value creation that may become one of the most disruptive markets of the coming decades. That's why we have applied the powerful method of Scenario Analysis – identifying the key factors and drivers shaping the development of humanoid robotics and synthesizing them into coherent and distinct images of the future.

The European Way: What role for machine makers in the future?

Europe's machine industry and companies do not compete in a vacuum. Humanoid robotics will be shaped by the development of global ecosystems. They encompass platform providers, component suppliers, integrators, operators, standards bodies, regulators, and of course investors. The key question is where European players will sit in the value chain of humanoid robotics, which roles they take, and whether they capture value beyond hardware. Component excellence remains essential, but it is not sufficient if robotic platforms, cutting-edge physical AI, interfaces, data access, and lifecycle services are controlled elsewhere.

The opportunity for Europe could lie in a distinctive "European way": human-centered, safe-by-design humanoid operation, with bounded autonomy, clear human decision authority, and practical accountability. This approach can become a competitive differentiator only if it is translated into workable standards and operating models that build trust without suppressing necessary innovation speed in a fast global competition. It also requires a radical change in ambition and investment. Other regions are showing strong commitment. Europe needs way more and faster pilot projects, much more private capital, stronger support of startups, and bolder industrial moves if it wants to shape markets rather than adopt them late. Incremental programs won't help.

Four scenarios for 2040

This study showcases four consistent scenarios for the future of humanoid robotics in 2040, offering a way to turn complexity and uncertainty into concrete alternative development paths and possible action. Each scenario outlines a specific approach to adoption, governance, and market structure beyond simple "best case" or "worst case" approaches. Each one is associated with different opportunities and risks for European machine makers:

Scenario 1: Trusted Helpers

Humanoid robots have turned into a normal layer of household infrastructure. They are affordable, highly safety-certified, and widely accepted as practical helpers under strict privacy and clear limits regarding tasks and behavior. For machine makers, this scenario means a high-volume market with intense cost pressure and fast development cycles. Humanoids have become systems that operate quietly, behave safely in close contact, and are easy to clean and repair. Infrastructure for certification, testing, service and repair is well established. Risk lies in platform dependence and commoditization if Europe remains only a sales market while development, production, operation and servicing of robot ecosystems are handled elsewhere.

Scenario 2: Premium Island

Humanoids diffuse as exclusive prestige objects for wealthy individuals and entities in premium environments. Performance and discretion dominate. High demand for deep personalization is costly and limits volumes. For machine makers, value mainly comes from high-margin subsystems (e.g., high-precision drives, dexterous hands, safety layers, perception components), longevity, certified upgrades, and lifetime service contracts. The main risk is structural: humanoid robotics could remain a side market if mass-market scaling happens outside of Europe. Another risk is that premium value increasingly depends on strong AI functionality, where Europe is investing too little compared to China and the US. This could relegate European firms to a role of hardware subcontractors unless stronger AI capabilities are ramped up.

Scenario 3: B2B Bot

Humanoids have become certified co-workers across commercial and public services. They address surging labor gaps under auditable safety and accountability. Adoption expands from services into selected industrial facility operations and logistics niches. For machine makers, this scenario offers scale and recurring value through a full stack: certified modules plus skills, integration, training, uptime guarantees, and re-certification. Risks include platform capture by global players, fast iteration cycles that challenge classical engineering cultures, and high liability exposure in human-proximate environments.

Scenario 4: Stuck in the Niche

In this scenario, humanoid robots remain confined to industrial and harsh environments with strict containment and human supervision. Public adoption stalls due to trust deficits safety concerns, security incidents, limited useability and fragmented standards. For companies, especially from the machine industry, this scenario concentrates on robust systems, safety and audit technology, turnkey integration into existing plants, tele-operation, and long-tail service contracts. The core risk is limited scale and regional niche economics. Deployment could remain concentrated in a few regions where regulation, certification capacity, and industrial demand support supervised use, while learning-curve effects remain weak compared to large-scale rollouts elsewhere.

Strategic implications across the scenarios

Across all four futures, the following overall strategic implications converge:

Physical AI changes automation beyond humanoids: Humanoids sit at the forefront of a broader automation shift—from deterministic systems to probabilistic, skill-based autonomy ("physical AI"). This shift will spill over into many automation formats: mobile manipulation, flexible logistics, hybrid cells, service robotics, and new machine concepts. The strategic focus is therefore not a narrow debate about form factors, but early engagement with physical AI capabilities and operating models that will shape the next generation of automation.

Trust and safety become the major scaling constraints: In households, public services, and co-work settings, adoption is exposed to the risk of trust shocks. A few high-profile incidents can hamper wider diffusion for years. Clarity and preparedness can be key stabilizers. This covers shared responsibilities, strict incident reporting rules, predictable remediation frameworks, and disciplined update governance. Safe operation becomes a core discipline with transparent evidence, before scale, not after.

Ecosystems shape value capture: Across the different scenarios, a small number of robotic platform ecosystems tend to define technical blueprints, interfaces, compliance logics, and issues like update rules. Even in premium and niche markets, platform control often determines data access, customer relationships, and long-term margins. Europe's competitiveness depends on actively pushing forward or being integrated early into widely used ecosystems and on shaping interfaces and standards, rather than being too late and competing as an interchangeable supplier only.

Modularity matters, but not as end-user tinkering: Modularity supports industrialization, serviceability, and safe updates. It enables faster rollout, faster repair, and controlled changes because functions and parts can be tested, documented, and certified at module level. For European machine makers, engaging in modular component families (joints, hands, sensor heads, power packs, safety layers) plus certification know-how can create positions that are hard to replace.

Europe needs smart regulation and decisive investment: Europe's safety and privacy tradition can be a major asset because it builds trust. It becomes a disadvantage if rules are overly complex, slow, or inconsistent across countries. This can raise costs without raising trust. A shift towards smart regulation is therefore critical. This means having aligned requirements, quick and predictable approval processes, and regulatory compliance and oversight that focuses on real-world risks and measurable safety outcomes. At the same time, this is an investment race. Without a radical change in speed and massive private investment, Europe risks buying, using, and complying with systems and technologies built elsewhere.

Near-term opportunities and risks that can shift the trajectory

The coming years represent a critical phase. Early decisions on standards, liability frameworks, interfaces, procurement rules, testbeds, workforce capabilities, and data governance will be difficult to revise later. Initial successes can attract private capital and accelerate progress. Early setbacks, by contrast, may reinforce distrust and trigger more restrictive regulatory responses. In this context, confidence is a strategic lever: coordinated roadmaps and credible reference deployments can align stakeholders, reduce investment risks, and help move the sector from isolated pilot projects towards scalable operating models.

Recommendations for Stakeholder Actions

Companies should make it a top strategic priority to evaluate the potential of humanoid robots and physical AI for their future business development. Opportunities span the entire emerging value chain: firms may position themselves as suppliers of key components, enter the market as humanoid OEMs, or become providers of production technologies tailored to humanoid manufacturing. At the same time, businesses should also assess the benefits of using humanoid robots within their own production facilities to boost productivity and flexibility.

Regardless of their chosen role, companies must actively monitor and engage with advances in physical AI—much of which is currently driven by progress in the humanoid sector. Even organizations that ultimately apply physical AI in other domains will gain a competitive edge by understanding these developments early and systematically. This includes simulation-first development, automated validation, and multidisciplinary teams that combine expertise in mechanics, safety engineering, and AI governance. It is also essential to secure early specifications within major robotic platform ecosystems and to focus on safety-critical subsystems where transaction costs are high. In addition, companies should build lifecycle services—such as re-certification and retrofitting—since customers increasingly value long-term usability and reliable operation.

Research institutions: Industry-led roadmaps need to specify real operating contexts and identify major blockers that could prevent future deployment of humanoid robots. Research is then asked to focus on identifying relevant measures and technologies that can break these bottlenecks. Some of them, for instance, are safe dexterous manipulation in unstructured environments, long-term reliability and robustness, controlled learning and update governance, fleet supervision concepts, and also human factors, such as social robotics or human-machine-interfaces. It is also vital that research institutions create accessible testbeds and training formats so that also SMEs can participate without bearing potentially high experimentation costs.

Politics and regulators: Political actors and regulatory bodies are asked to set clear, harmonized rules, e.g. on topics like liability, incident reporting, and data logging for co-working settings and public deployments. All regulations must ensure practicability and cost-effectiveness from the outset. They should provide predictable, workable approval routes that build trust without unnecessarily slowing progress.

Europe needs to ramp up a supply chain of the needed components and technologies to build up production at scale. Production in Europe is key. Government programmes need to support that goal bearing in mind the massive efforts and investments present in major competition regions like China and the US. Furthermore, public funding should leverage private investment. This may jumpstart the first scaling of Europe-made humanoid technology.

Public procurement can provide an impetus for ramp-up. Procurement rules may require auditable operation, transparent incident reporting and learning processes, and formal mechanisms for worker involvement wherever humanoids operate alongside humans. In the EU, it is also important to support shared roadmaps and joint testbeds across member states rather than parallel national pilot projects. Privacy-preserving improvements (e.g., on-device and federated learning) under clear safeguards is also of high relevance. To take up speed in the global robotics race, Europe should make extensive use of the concept of regulatory sandboxes.

VDMA: A core task is to build a strong stakeholder network across OEMs, suppliers, users, research, safety actors, and policymakers to enable continuous exchange and collaboration. The aim is to act as a catalyst for building up a complete supply chain for the production of world-leading humanoids in Europe at scale. Important measures on this way are developing studies, strategy papers and roadmaps for humanoid robotics and physical AI that provide much needed orientation for the VDMA members. In parallel, VDMA will foster the use of humanoids in the manufacturing facilities of its own member companies including SMEs, generating valuable application know-how that

can be fed back into the development of the technology. On the policy side, VDMA will engage in an intensive dialogue with policymakers to advocate bold and workable policies for European excellence in humanoid robotics.

Conclusion and call to action

Humanoid robotics is not only a new robot category; it is the entry point into a broader shift toward physical AI and probabilistic, skill-based automation. The story is not written yet. Any of the different futures described here could come to pass, and Europe's role is still open. But the window for shaping robotic and digital platforms, standards, operating models, and value capture is narrow. Others are investing at scale and shortening their learning curves. Europe can lead - but only with high speed and bold action: with coordinated cooperation, smart regulation, shared roadmaps, real testbeds, scalable service and a decisive increase in private investment. Otherwise, Europe is forced to mainly adopt what others build. Apparently, there is no future without Humanoids – all stakeholders should join forces to ensure that Europe plays a leading role in shaping their production, operation, and application alike.