



Physical AI – the rise of the machines

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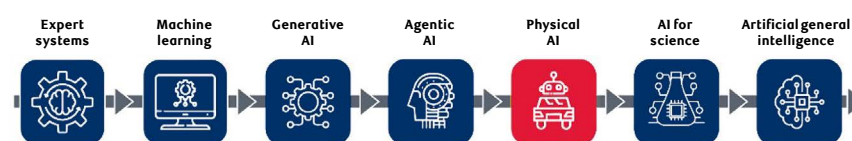
“Physical AI represents AI’s next evolution: embodied systems that see, think and act in the real world, extending intelligence beyond digital tasks.”

AI is evolving from digital automation to physical AI, where intelligent robots, vehicles, and drones perceive, learn, and adapt to the real world. Here we look at humanoid robots, which are emerging as one of the most visible and potentially scalable applications of this trend.

Physical AI

Physical AI represents AI’s next evolution: embodied systems that see, think and act in the real world, extending intelligence beyond digital tasks (Exhibit 1). It embeds intelligence into systems, enabling them to perceive their surroundings, make decisions and act autonomously.

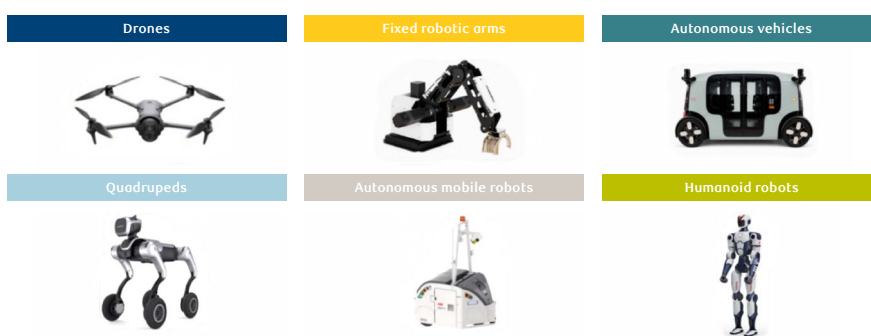
Exhibit 1: AI has evolved from digital to physical domains



Source: AI left the chat! Physical AI Primer, BofA Global Research, as at February 2026.

Physical AI takes many forms, each designed for specific environments and applications (Exhibit 2). These include drones for aerial delivery, surveillance and inspection; fixed robotic arms for precise, repetitive tasks in manufacturing, surgery and logistics; autonomous vehicles for transporting people and goods; quadruped robots for navigating unstructured terrain; autonomous mobile robots for general-purpose movement, handling and delivery; and humanoid robots built to operate in human-centred environments such as factories, warehouses, homes and hospitals.

Exhibit 2: Physical AI systems take diverse forms, each optimised for a specific environment and purpose



Source: AI goes physical: navigating the convergence of AI and robotics, Deloitte Insights, as at December 2025.

Machines that can sense, think and act

Humanoid robots are a human-like form designed to replicate aspects of human movement, perception and interaction, enabling them to operate in complex, unstructured environments designed for people.

Humanoid robots differ from traditional industrial robots in both their physical design and intended operating environment.

Industrial robots are generally installed in structured settings and programmed for a relatively narrow set of repetitive tasks. Humanoids are intended to operate in more variable environments, often alongside people, and to perform multiple tasks using a combination of mobility, perception and dexterity (Exhibit 3).

Exhibit 3: Key differences between humanoid robots and industrial robots

	Humanoid robots	Industrial robots
Characteristics	Small size, light weight	Large size, heavy weight
Tasks	Multifunctional in daily tasks including interaction with humans	Repetitive tasks such as welding, assembly and packaging
Working environment	Unstructured	Structured
Structure	Complex	Relatively simple
Mobility	Usually bipedal	Fixed
Precision requirements	Medium for general tasks	Relatively high
Application scenarios	Industrial, commercial, service, household	Industrial manufacturing

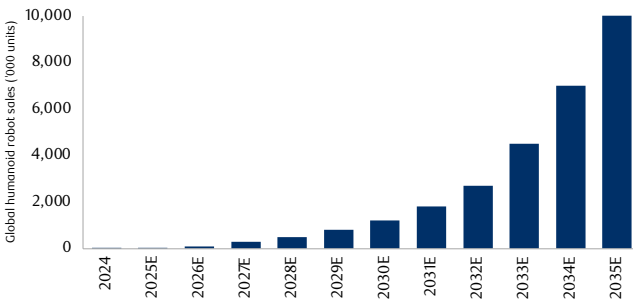
Source: Humanoid robots 101, BofA Research, April 2025; Humanoid robots - Rise of the robots, Macquarie Research, as at March 2025.

A market moving from pilot to scale

Humanoid robotics remains in the early stages of commercial adoption, with most deployments still limited to pilot programmes rather than scaled operations. However, the industry is expected to follow a steep growth trajectory as technology matures and production scales to address the widening and persistent labour gap.

Humanoid robot sales are projected to grow at an 86% CAGR, rising from approximately 20,000 units in 2025 to 10 million units annually by 2035E (Exhibit 4). This will support market expansion from roughly USD7bn in 2025 to USD100bn by 2033E, highlighting the sector’s significant long-term investment potential (Exhibit 5).

Exhibit 4: Humanoid robot sales set to rise to 10m units annually by 2035

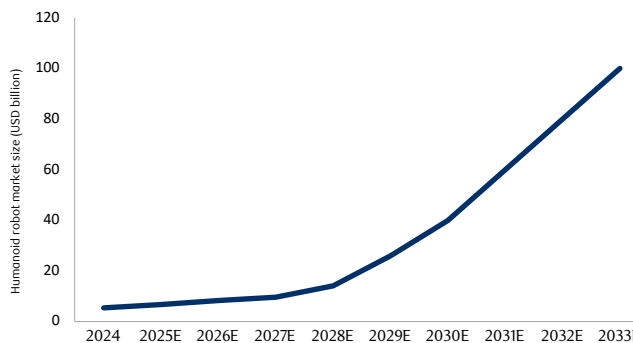


Source: AI left the chat! Physical AI Primer, BofA Global Research, as at February 2026.

“Humanoid robot sales are projected to grow at an 86% CAGR, rising from approximately 20,000 units in 2025 to 10 million units annually by 2035E.”

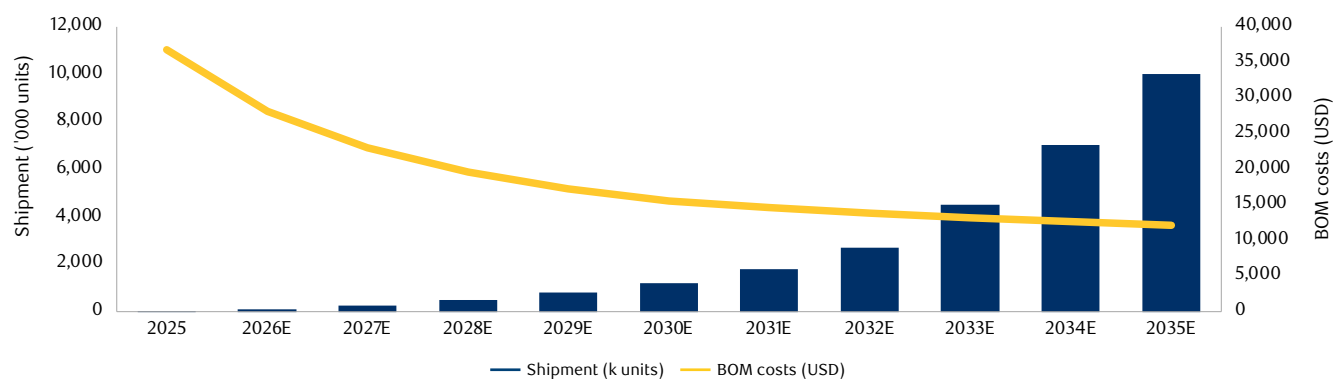
This expansion will also be supported by falling hardware costs as manufacturing scales, components become standardised and technology advances. BofA estimates that unit costs could fall below USD13,000 by 2035E, particularly with China-based component sourcing, strengthening the case for deployment across labour-intensive industrial applications (Exhibit 6).

Exhibit 5: Global humanoid market to grow at a CAGR of 40% between 2025-33E



Source: AI left the chat! Physical AI Primer, BofA Global Research, as at February 2026.

Exhibit 6: Humanoid bill of materials (BOM) cost expected to fall below USD13,000 by 2035E as shipments expand



Source: Humanoid robots 101, BofA Research, as at April 2025.

Humanoid robots will be deployed across a growing range of applications, while near-term adoption is likely to remain concentrated in industrial settings driven by controlled environments and repetitive workflows. However, in the long run, humanoid robots are expected to expand from manufacturing, automotive and warehouse operations into retail, hospitality, healthcare, homes and education sectors.

Humanoid Original Equipment Manufacturer (OEM) landscape: regional strategies are diverging

The emerging OEM landscape is geographically diverse, with China and the US best positioned to lead the first phase of scale-up. Given the supply chain overlap with automotive manufacturing, a number of companies in these industries are also repurposing existing production capacity to develop humanoids (Exhibit 7).

Exhibit 7: Several automakers have partnered with humanoid OEMs or are utilising their own production capacity to develop and deploy humanoid robots within their manufacturing facilities

Humanoid OEMs	Model	Deployment site/Partner	Main tasks
Tesla	Optimus (Gen 2)	Tesla giga factories	Battery cell handling, sorting
Boston Dynamics	Atlas (electric)	Hyundai Motor Group	Auto-parts handling, sub-assembly
Figure AI	Figure 02	BMW manufacturing	Sheet metal placement, chassis handling
Agility Robotics	Digit	Amazon/ GXO logistics	Empty tote recycling, conveyor induction
Apptronik	Apollo	Mercedes-Benz	Parts-kitting, line-side delivery
Sanctuary AI	Phoenix	Magna (Steyr plant)	Precision assembly (transmission)
UBTECH	Walker S	NIO/Dongfeng	Seatbelt inspection, emblem install
UBTECH	Walker	BYD, Geely Auto, Zeekr	Production-line tasks in smart factory environments
1X Technologies	EVE (wheeled)	ADT commercial	Night patrol, anomaly detection
Unitree	H1 (biped)	Chinese auto suppliers	Material handling, logistics
Hexagon Robotics	AEON	BMW manufacturing	Industrial inspection, chassis handling
Xiaomi	Cyber One	Xiaomi EV factory	Assembly line screw driving and bin handling
Agility Robotics; Humanoid	Digit; Alpha	Schaeffler	Material handling
XPeng	Iron	XPeng's Guangzhou factory	Assembly tasks
Chery	AiMOGA Mornine M1	Chery 4S dealership in Kuala Lumpur	Automotive retail - handles vehicle introductions, customer welcoming, test-drive guidance, and task switching in a live service setting

Source: AI left the chat! Physical AI Primer, BofA Global Research, February 2026; Physical AI/Humanoid, CLSA, March 2026; AiMOGA Mornine M1 Multilingual AI Powered Humanoid Robot, Robots International.

China: manufacturing breadth and cost advantages

China has emerged as the fastest-growing humanoid robotics market, supported by strong government backing, extensive manufacturing capabilities and a broad domestic supplier base. Its innovation lead is reflected in approximately 7,700 humanoid-related patents filed over the past five years, versus 1,560 in the US and 1,100 in Japan¹. Unitree, Agibot and UBTECH are the major humanoid OEMs in China with Unitree and Agibot accounting for more than 70% of 2025 output combined².

US: AI and vertical integration

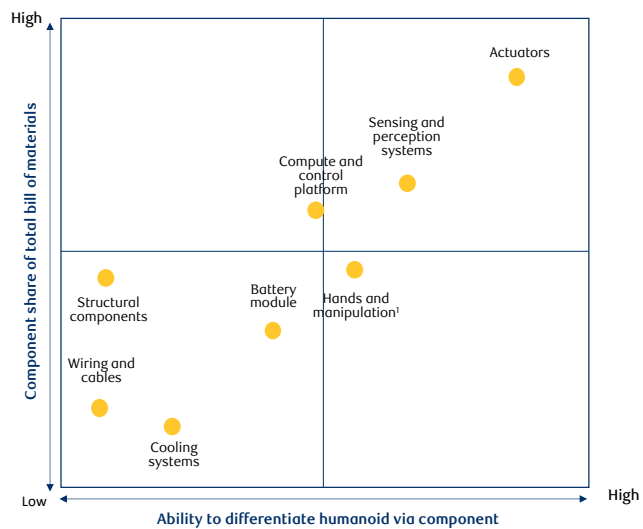
The US is pursuing a more vertically integrated model, with companies developing proprietary actuators, control systems and AI software in-house rather than relying predominantly on external suppliers. Its automation demand case is reinforced by manufacturing reshoring and labour shortages. Tesla, Figure AI, Agility Robotics, Boston Dynamics and Apptронik are the leading humanoid OEMs in the US.

Supply chain components

A humanoid robot replicates the human form, combining semiconductors and AI software in its brain with sensors, actuators, wiring, connectors and a lightweight battery-powered body (Exhibit 8). It operates through a closed-loop sense–think–act system that converts environmental data into coordinated physical movement, making every component’s performance critical to the robot’s overall capability.

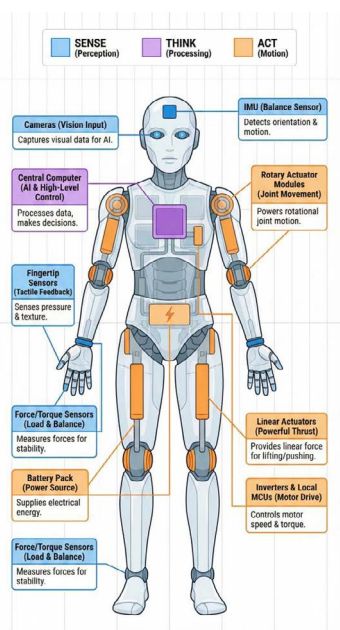
The supplier ecosystem for critical humanoid components remains nascent, creating significant potential for production scale-up. McKinsey analysis suggests that actuators and sensors are likely to represent the key supply-chain bottlenecks in humanoid robotics, given their least mature supplier ecosystems³ (Exhibit 9). As production scales, component suppliers in these subsystems stand to benefit the most from the sector’s expansion.

Exhibit 9: Actuators and sensors are high-cost and critical components in humanoid robots



Source: Turning humanoid supply chain constraints into billion-dollar wins, McKinsey, as at April 2026.
¹: only if procured separately, otherwise hands and manipulation are part of actuators and sensors.

Exhibit 8: Humanoid robot – core components



Brain - AI models and semiconductors

- Foundation models
- Data science and analytics
- Simulation and vision software
- Vision and compute semiconductors
- Memory semiconductors
- Semiconductor designers and fabrication

Body - sensors, actuators, body structure, power system

Sensors	Actuators and actuator parts	Body, wiring, thermal	Power system
▪ Cameras and vision sensors ▪ Radar and LIDAR ▪ Magnetic sensors ▪ Force and torque sensors ▪ Inertial measurement units (IMU) ▪ Tactile sensors ▪ Analog semiconductors	▪ Motors (Coreless motors, brushless DC motors) ▪ Bearing ▪ Encoders ▪ Gearing and reducers (Harmonic /planetary reducers) ▪ Screws (Planetary roller screws and ball screws)	▪ Aluminium castings ▪ Wires and connectors ▪ Thermal (Pumps, Battery Cooling, etc.)	▪ Battery packs

Source: The Humanoid 100: mapping the humanoid robot value chain, MS Research, as at February 2025.

¹ Turning humanoid supply chain constraints into billion-dollar wins, McKinsey, April 2026.
² AI left the chat! Physical AI Primer, BofA Global Research, February 2026.
³ Turning humanoid supply chain constraints into billion-dollar wins, McKinsey, April 2026.

Actuators and sensors: the most important investment layer

Actuators are the muscles responsible for movement, balance and force and are expected to be the most expensive component, accounting for more than 50% of total BOM costs by 2030E (Exhibit 10). Actuators play a central role in robots' performance by integrating motors, drives, transmissions and sensors into compact modules and are deployed across both rotary and linear joints.

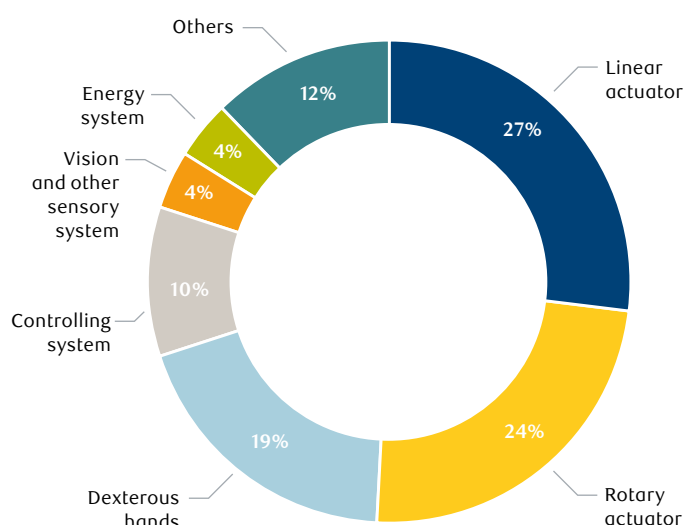
Within the actuator supply chain, reducers and screws emerge as the most compelling stock-picking opportunities, given their high average selling prices, technical entry barriers and import-substitution potential. Harmonic reducers are expected to benefit most from humanoid adoption, given their widespread use in compact rotary joints. On the linear side, ball screws and planetary roller screws are critical actuator components, with planetary roller screws projected to represent the highest-value component at approximately 15% of total BOM by 2030E⁴. It is estimated that humanoid adoption could expand the global precision screw market by approximately 24% by 2030E⁵.

Sensors form the robot's nervous system, enabling perception and environmental awareness. As humanoid adoption scales, the industry is shifting from discrete point sensors toward distributed sensing architectures including tactile sensors, sensing skins and force-torque measurement⁶.

Summary

Humanoid robots are emerging as a potential solution to persistent labour shortages, particularly in industries facing repetitive and physically demanding jobs. These robots are more likely to augment rather than replace human workers.

Exhibit 10: Actuators to account for over 50% of the total humanoid BOM cost by 2030E



Source: AI left the chat! Physical AI Primer, BofA Global Research, as at February 2026.
Data denotes BOM cost breakdown by module/system, 2030E.

While commercial deployment is currently concentrated in structured environments, particularly manufacturing, continued advances in AI, dexterity, and mobility could allow these robots to perform an increasing share of physical tasks in unstructured environments, such as the household sector.

Although adoption remains at an early stage, declining hardware costs are expected to improve affordability and gradually narrow the gap with human labour costs.

The key beneficiaries are likely to be major suppliers of critical components, especially sensors and actuators.

⁴ AI left the chat! Physical AI Primer, BofA Global Research, February 2026.

⁵ Global Humanoid Robot Components, Daiwa Capital Markets, June 2026.

⁶ Global Humanoid Robot Sensors Market Research Report 2026, QY Research, March 2026.

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Richard is a portfolio manager on the RBC Emerging Markets Equities team and is responsible for top-down strategy. During his tenure at the firm, Richard has also been responsible for research on China. Prior to joining the firm in 2013, he spent three years at UK asset manager Aviva Investors, providing fundamental equity analysis in the energy and materials sectors within global emerging markets. Richard began his career in the investment industry in 2005 as an analyst in the mergers and acquisitions team of HSBC.

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