Humanoid robots could drive new demand for critical minerals

Published 9 March 2026

Baoqi Zhu
Associate Director, Quantitative Research & Multi Asset Solutions

Key Takeaways

- Humanoids are built around two mineral-heavy systems: actuators drive rare earth magnet and copper demand, while batteries drive lithium demand.
- Recent AI progress makes large-scale deployment more plausible. If humanoids move from pilots to fleets, mineral demand could rise quickly.
- Supply may struggle to respond. New mines and processing projects take many years to come online, so even moderate demand surprises can tighten markets.
- Another risk is supply-chain concentration. Processing and magnet-making are often more concentrated than mining, which increases geopolitical and pricing risk if deployment scales.

Critical minerals are becoming more important. Demand is supported by grid upgrades, rapid EV[1] adoption, and rising geopolitical tension around supply chains. But one potential driver is still underappreciated. The rise of humanoid robots could add a new layer of demand and increase the risk of deficits in some minerals.

When Jensen Huang unveiled new physical AI[2] models for robots, he said the "ChatGPT moment for physical AI is here." That statement is not only relevant for AI, it also raises a practical question for investors: what does large-scale humanoid deployment mean for critical minerals?

Building a humanoid: the critical minerals required

Actuators: NdPr and copper

A humanoid needs a lot of motors to move its joints. For example, Tesla's Optimus Gen 2[3] uses 28 motors for major joints such as shoulders, elbows, waist, and legs. It also uses extra small motors in the hands to move fingers and improve control.

Many of these motors use strong permanent magnets to make the motor small but powerful. These magnets are usually made from a material called NdFeB[4] and contain rare earths, mainly neodymium and praseodymium (NdPr). Copper is the other key input, and it is used heavily in motor windings.

As humanoids develop, more degrees of freedom will be needed to improve dexterity, especially in hands. In turn, this means more actuators and motors will be required and, therefore, more minerals needed (provided permanent magnet motors remain standard).

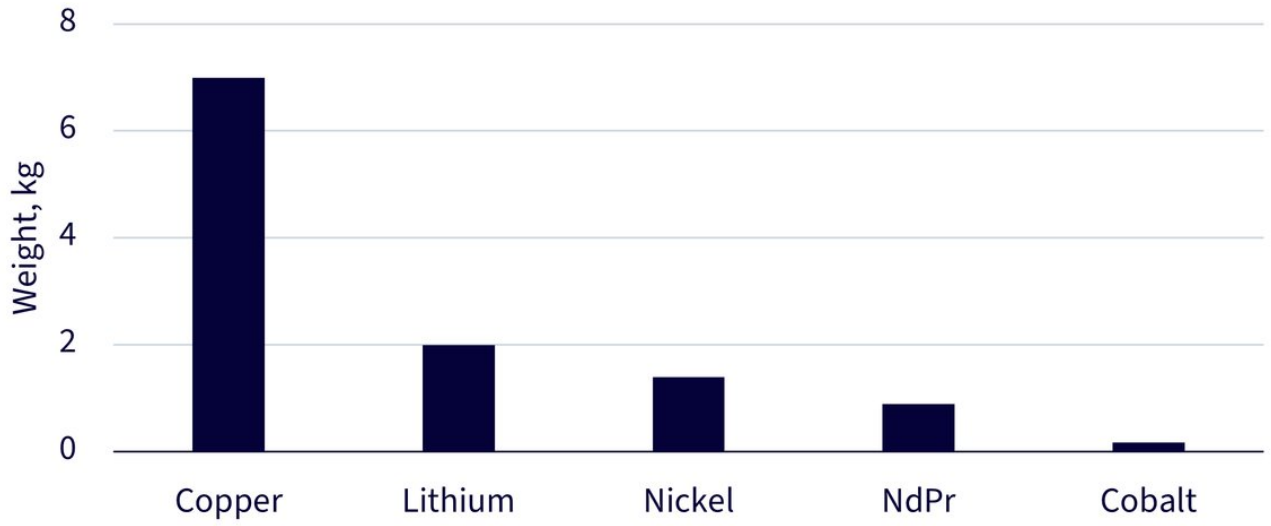
Battery packs: Lithium, nickel, cobalt, copper

Unlike EVs, humanoids need a smaller battery pack to drive the body. Therefore, the batteries with higher energy density like Lithium Nickel Cobalt Aluminium Oxide (NCA) and Nickel Manganese Cobalt (NMC) batteries are more suitable for humanoid applications. Copper is also key for batteries and is used for the internal metal layers and connections.

Wiring, chips, and charging

Copper shows up again in the robot's wiring, which carries power and data through the body and joints. Charging infrastructure can add more copper as fleets scale. Chips may use some materials like gallium, but the quantities are usually tiny compared with copper.

Figure 1: Estimated weights of critical minerals required per humanoid



Source: Morgan Stanley: "The robots are coming…for critical minerals", 21 May 2025. The estimates are for the base case. **Forecasts are not an indicator of future performance and any investments are subject to risks and uncertainties.**

Why recent tech progress matters for minerals demand

The demand for critical minerals from humanoids depends on the scale of deployment. Recent developments are making the case even more plausible and, if humanoids move from pilots to fleets, minerals demand will scale with unit volumes.

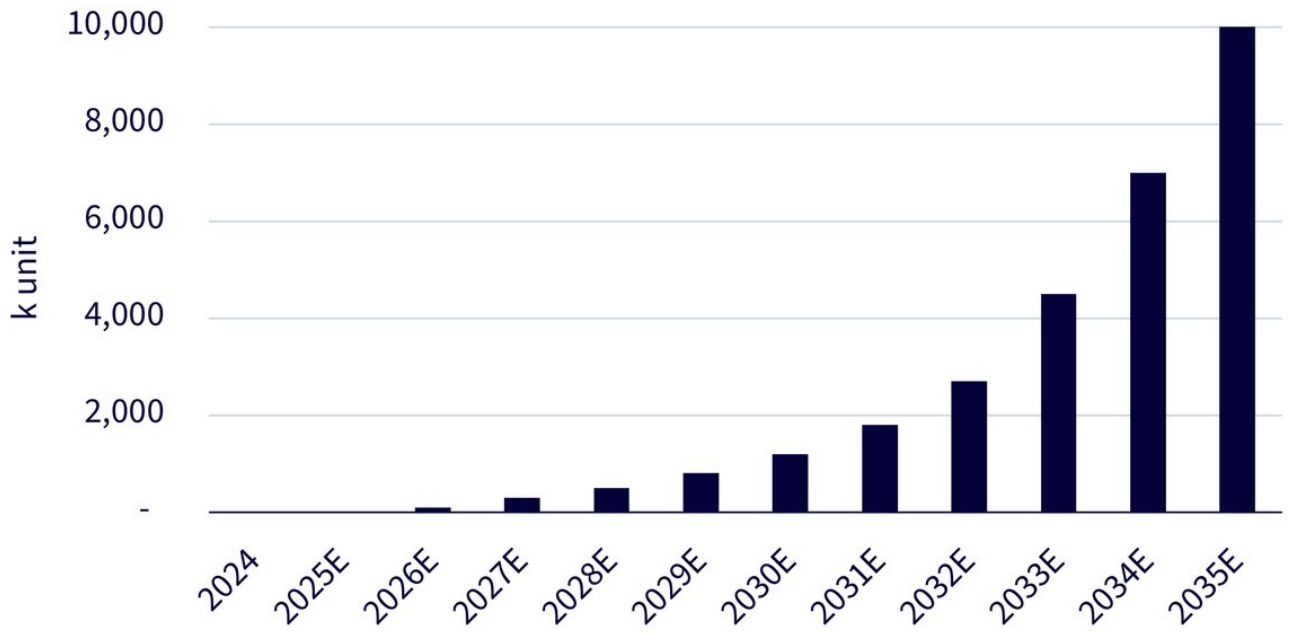
From a software perspective, training robots to operate in the physical world has, historically, been expensive and time consuming compared to training a model in the digital world, as data needs to be collected from physical experiments. However, as vision language models develop and more simulation

and synthetic data is applied in training, developers can generate more diverse situations and iterate faster than physical testing alone. Together, they could shorten development cycles and lower integration costs for manufacturers.

Regarding the hardware, as designs standardise and production scales, key component costs, like actuators, should fall. Together with the developments in software, humanoids will likely become more intelligent and more affordable going forward.

Wall Street gives relatively positive forecasts on humanoid deployment. Morgan Stanley projects that the cumulative stock of humanoids may reach 1bn units and annual sales reach 200mn units by 2050[5]. The Bank of America estimates that 10mn units of humanoids will be deployed by 2035[6]. Such figures also reflect the sentiments from the markets.

Figure 2: Annual humanoid robot shipments projection



Source: Bank of America: "AI left the chat! Physical AI Primer". 05 February 2026. **Forecasts are not an indicator of future performance and any investments are subject to risks and uncertainties.**

Challenge on supply chains

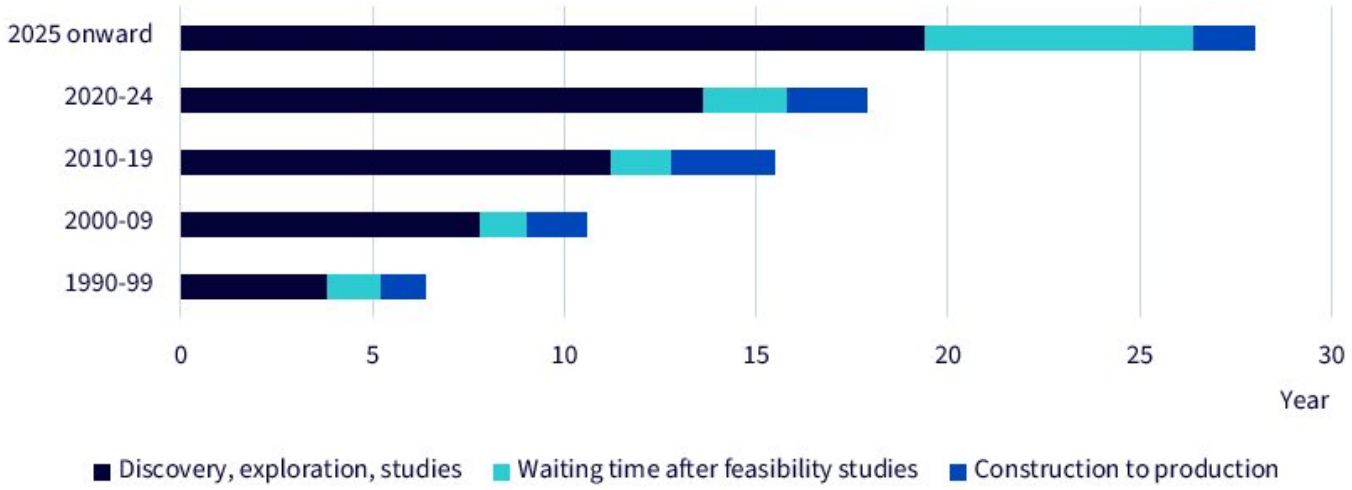
The potential large-scale deployment of humanoids could affect trade balances through demand for critical minerals. Take lithium as an example. Global lithium production in 2024 was around 240,000 tonnes. If we assume a humanoid requires 2 kg of lithium, then 10 million humanoids would need 20,000 tonnes of lithium, which is roughly 8% of 2024 global production. Although large-scale humanoid deployment has not yet happened, there are two supply-chain features of relevant critical minerals that need to be considered:

1. Project lead times and the risk of deficits

Humanoid demand, if it arrives, could grow fast and supply is unlikely to keep up. New mines take a long time to reach production, and lead times have lengthened since the 1990s. Across many projects, moving from discovery to production often takes well over 10 years, and recent cohorts are closer to 18 years on average. Most of that time is not construction. It is spent on exploration, feasibility work, permits, and financing.

This creates a clear risk of deficits. If humanoid deployments accelerate while EV and grid demand stay strong, demand for key minerals could rise faster than new supply.

Figure 3: Average lead time for mines since 1990

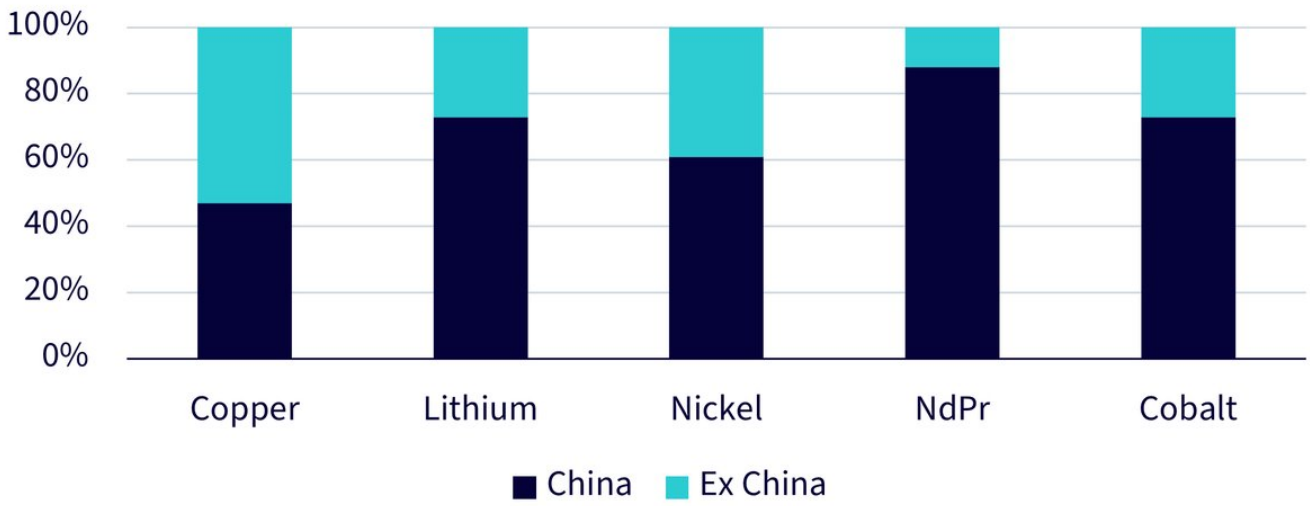


Source: S&P Global: From 6 years to 18 years: The increasing trend of mine lead times. 11 April 2025. **Historical performance is not an indication of future performance and any investments may go down in value.**

2. China concentration and geopolitical risk

For several minerals linked to humanoids, dependence is often higher in processing than in mining. Rare earths are the clearest case. Mining is spread across countries, but separation, metal making, and permanent magnet production are far more concentrated, with China being dominant. Battery materials show a similar pattern, with China and Chinese-owned firms deeply involved across refining and manufacturing. This creates a concentration risk in supply chains.

Figure 4: Refined supply of major critical minerals related to humanoids



Source: Morgan Stanley, Wood Mackenzie. China shares include both Chinese and Chinese-owned enterprises. Nickel refined supply doesn't appear to be concentrated in China, until Indonesia supply (which is estimated to be at least 75% China ownership) is factored. **Forecasts are not an indicator of future performance and any investments are subject to risks and uncertainties.**

Investing in the opportunity with WisdomTree

- WisdomTree Strategic Metals and Rare Earths Miners UCITS ETF (RARE) provides diversified, yet targeted access to the value chain of metals and rare earth elements (through miners) that are required for an increasingly energy-hungry world.
- WisdomTree Strategic Metals UCITS ETF (WENU) provides refined exposure to a diversified basket of essential metals needed for electrification, energy security, decarbonisation and digital infrastructure.
- WisdomTree Physical AI Humanoids and Drones UCITS ETF (WPAI) provides targeted exposure to the physical AI transformation by investing in companies developing embodied, autonomous systems and the hardware, components and platforms that enable intelligent machines to operate in real-world environments.

[1] Electric vehicle.
[2] Artificial intelligence.
[3] Optimus Gen 2 is an advanced, lightweight humanoid robot designed by Tesla for industrial and household tasks.
[4] NdFeB = an alloy of neodymium, iron and boron.
[5] Source: Morgan Stanley: "A $5 Trillion Global Market", 29 April 2025.
6 Source: Bank of America: “AI left the chat! Physical AI Primer”. 05 February 2026.

Important Risks Related to this Article

IMPORTANT INFORMATION

Marketing communications issued in the European Economic Area ("EEA"): This document has been issued and approved by WisdomTree Ireland Limited, which is authorised and regulated by the Central Bank of Ireland.

Marketing communications issued in jurisdictions outside of the EEA: This document has been issued and approved by WisdomTree UK Limited, which is authorised and regulated by the United Kingdom Financial Conduct Authority.

WisdomTree Ireland Limited and WisdomTree UK Limited are each referred to as "WisdomTree" (as applicable). Our Conflicts of Interest Policy and Inventory are available on request.

This marketing communication has been prepared for professional investors, but the WisdomTree products set out in this document may be available in some jurisdictions to any investors, subject to applicable laws and regulations. As the product may not be authorised or its oering may be restricted in your jurisdiction, it is the responsibility of every person or entity to satisfy themselves as to the full observance of the laws and regulations of the relevant jurisdiction. Prior to any application investors are advised to take all necessary legal, regulatory, tax and investment advice on the suitability and consequences of an investment in the products. Past performance is not a reliable indicator of future performance. Any historical performance included in this document may be based on back testing. Back testing is the process of evaluating an investment strategy by applying it to historical data to simulate what the performance of such strategy would have been. Back tested performance is purely hypothetical and is provided in this document solely for informational purposes. Back tested data does not represent actual performance and should not be interpreted as an indication of actual or future performance. The value of any investment may be aected by exchange rate movements. Any decision to invest should be based on the information contained in the appropriate prospectus and aer seeking independent investment, tax and legal advice. These products may not be available in your market or suitable for you. The content of this document does not constitute investment advice nor an oer for sale nor a solicitation of an oer to buy any product or make any investment.

An investment in exchange-traded products ("ETPs") is dependent on the performance of the underlying index, less costs, but it is not expected to match that performance precisely. ETPs involve numerous risks including among others, general market risks relating to the relevant underlying index, credit risks on the provider of index swaps utilised in the ETP, exchange rate risks, interest rate risks, inflationary risks, liquidity risks and legal and regulatory risks.

The information contained in this document is not, and under no circumstances is to be construed as, an advertisement or any other step in furtherance of a public oering of shares in the United States or any province or territory thereof, where none of the issuers or their products are authorised or registered for distribution and where no prospectus of any of the issuers has been filed with any securities commission or regulatory authority. No document or information in this document should be taken, transmitted or

distributed (directly or indirectly) into the United States. None of the issuers, nor any securities issued by them, have been or will be registered under the United States Securities Act of 1933 or the Investment Company Act of 1940 or qualified under any applicable state securities statutes.

This document may contain independent market commentary prepared by WisdomTree based on publicly available information. Although WisdomTree endeavours to ensure the accuracy of the content in this document, WisdomTree does not warrant or guarantee its accuracy or correctness. Any third party data providers used to source the information in this document make no warranties or representation of any kind relating to such data. Where WisdomTree has expressed its own opinions related to product or market activity, these views may change. Neither WisdomTree, nor any ailiate, nor any of their respective oicers, directors, partners, or employees accepts any liability whatsoever for any direct or consequential loss arising from any use of this document or its contents.

This document may contain forward looking statements including statements regarding our belief or current expectations with regards to the performance of certain assets classes and/or sectors. Forward looking statements are subject to certain risks, uncertainties and assumptions. There can be no assurance that such statements will be accurate and actual results could dier materially from those anticipated in such statements. WisdomTree strongly recommends that you do not place undue reliance on these forward-looking statements.

WisdomTree Issuer ICAV

The products discussed in this document are issued by WisdomTree Issuer ICAV (“WT Issuer”). WT Issuer is an umbrella investment company with variable capital having segregated liability between its funds organised under the laws of Ireland as an Irish Collective Asset-management Vehicle and authorised by the Central Bank of Ireland (“CBI”). WT Issuer is organised as an Undertaking for Collective Investment in Transferable Securities (“UCITS”) under the laws of Ireland and shall issue a separate class of shares ("Shares”) representing each fund.

The Fund is described in a Key Information Document (KID) or Key Investor Information Document (KIID) for UK investors, and the prospectus of WT Issuer (“WT Prospectus”). A copy of the WT Prospectus and the KID / KIID is available, for EEA/UK only, in English at www.wisdomtree.eu. Where required under national rules, the KID will also be available in the local language of the relevant EEA Member State. Investors should read the WT Prospectus before investing and should refer to the section of the WT Prospectus entitled »Risk Factors¼ for further details of risks associated with an investment in the Shares.

The summary of investor rights associated with an investment in the fund is available in English on WisdomTree Europe¼s website. WisdomTree Management Limited may decide to terminate the arrangements made for the marketing of its collective investment undertakings. In such circumstances, shareholders in the aected EEA Member State will be notified of this decision and will be provided with the opportunity to redeem their shareholding in the fund free of any charges or deductions for at least 30 working days from the date of such notification.

For Investors in Switzerland:

This document constitutes an advertisement of the financial product(s) mentioned herein.

The prospectus (in English only) and the key investor information documents (KID) (in German, French and Italian) are available from WisdomTree¼s website: https://www.wisdomtree.eu/en-ch/resource-library/prospectus-and-regulatory-reports

For WisdomTree UCITS products only: the representative and paying agent of the ETPs in Switzerland is Société Générale Paris, Zurich Branch, Talacker 50, PO Box 5070, 8021 Zurich, Switzerland. The prospectus, the key investor information documents (KIID), the articles of association and the annual and semi-annual reports of the sub-funds are available free of charge from the representative and paying agent. As regards distribution in Switzerland, the place of jurisdiction and performance is at the registered seat of the representative and paying agent. Some of the sub-funds referred to in this document may not have been registered with the Swiss Financial Market Supervisory Authority ("FINMA"). In Switzerland, such sub-funds that have not been registered with FINMA may only be available to Qualified Investors.

For Investors in France:

The information in this document is intended exclusively for professional investors (as defined under the MiFID) investing for their own account and this material may not in any way be distributed to the public. The distribution of the Prospectus and the oering, sale and delivery of Shares in other jurisdictions may be restricted by law. WT Issuer is a UCITS governed by Irish legislation, and approved by the Financial Regulatory as UCITS compliant with European regulations although may not have to comply with the same rules as those applicable to a similar product approved in France. The Fund has been registered for marketing in France by the Financial Markets Authority (Autorité des Marchés Financiers) and may be distributed to investors in France. Copies of all documents (i.e. the Prospectus, the Key Investor Information Document, any supplements or addenda thereto, the latest annual reports and the memorandum of incorporation and articles of association) are available in France, free of charge at the French centralizing agent, Societe Generale at 29, Boulevard Haussmann, 75009, Paris, France. Any subscription for Shares of the Fund will be made on the basis of the terms of the prospectus and any supplements or addenda thereto.

For Investors in Malta: This document does not constitute or form part of any oer or invitation to the public to subscribe for or purchase shares in the Fund and shall not be construed as such and no person other than the person to whom this document has been addressed or delivered shall be eligible to subscribe for or purchase shares in the Fund. Shares in the

Fund will not in any event be marketed to the public in Malta without the prior authorisation of the Maltese Financial Services Authority.

For Investors in Monaco: This communication is only intended for duly registered banks and/or licensed portfolio management companies in Monaco. This communication must not be sent to the public in Monaco.

For Investors in Israel: Oering materials for the oering of the Shares and securities have not been filed with or approved or disapproved by the United States Securities and Exchange Commission or any other state or federal regulatory authority, nor has any such regulatory authority passed upon or endorsed the merits of this oering or passed upon the accuracy or completeness of any oering materials. Any representation to the contrary is unlawful. The products mentioned herein have not been approved by the Israel Securities Authority and will only be distributed to Israeli residents in a manner that will not constitute “an oer to the public” under sections 15 and 15a of the Israel Securities Law, 5728-1968 (“the Securities Law”) or section 25 of the Joint Investment Trusts Law, 5754-1994 (“the Joint Investment Trusts Law “), as applicable. The products are being oered to a limited number of investors (35 investors or fewer during any given 12 month period) and/or those categories of investors listed in the First Addendum (“the Addendum”) to the Securities Law, “Sophisticated Investors”) who in each case have provided written confirmation that they qualify as Sophisticated Investors, and that they are aware of the consequences of such designation and agree thereto; in all cases under circumstances that will fall within the private placement or other exemptions of the Joint Investment Trusts Law, the Securities Law and any applicable guidelines, pronouncements or rulings issued from time to time by the Israel Securities Authority.

This prospectus or this document may not be reproduced or used for any other purpose, nor be furnished to any other person other than those to whom copies have been sent. Any oeree who purchases a product is purchasing such product for its own benefit and account and not with the aim or intention of distributing or oering such product to other parties (other than, in the case of an oeree which is a Sophisticated Investor by virtue of it being a banking corporation, portfolio manager or member of the Tel-Aviv Stock Exchange, as defined in the Addendum, where such oeree is purchasing a product for another party which is a Sophisticated Investor).

Nothing in this document should be considered investment advice or investment marketing as defined in the Regulation of Investment Counselling, Investment Marketing and Portfolio Management Law, 5755-1995. Investors are encouraged to seek competent investment counselling from a locally licensed investment counsel prior to making the investment. A recipient of this document may be required to provide confirmation that it is a Sophisticated Investor purchasing a product for its own account or, where applicable, for other Sophisticated Investors.