Viewpoint | Citi Research

10 Jun 2026 12:08:44 ET | 13 pages

China Materials

AI PCB Upgrade: Bottleneck Shifting Upstream to CCL and E-fabric

CITI'S TAKE

We hosted a joint analyst call to discuss the AI PCB supply chain from the perspectives of PCB, CCL and upstream E-fabric. The key message is that AI server demand is driving not only volume growth, but also a structural upgrade in PCB layer count, CCL material grade, copper foil and glass cloth specifications. The call suggests capacity growth is the fastest in PCB, followed by CCL and E-fabric, while pricing leverage moves in the opposite direction. PCB makers can largely pass through AI-related material cost increases, but margin upside is more limited as price hikes are mainly cost pass-through. We see better earnings leverage in CCL and E-fabric, where supply is more constrained, and price hikes are more direct. China Jushi remains our preferred China materials beneficiary.

Anna Wang[AC]
+852-2501-2739
anna.d.wang@citi.com

Karen Huang[AC]
+852-2501-2755
karen.xw.huang@citi.com

Jack Chen[AC]
+886-2-8726-9091
jack1.chen@citi.com

Jack Shang, CFA
+852-2501-2441
jack.shang@citi.com

Jimmy Feng
+852-2501-7588
jimmy.feng@citi.com

Cynthia Wu
+852-2868-7813
cynthia.d.wu@citi.com

Capacity growth vs pricing leverage — Supply growth is the fastest in PCB, followed by CCL and E-fabric. PCB makers are expanding most aggressively, but AI-related price increases are largely cost pass-though. CCL capacity growth is only c. 20%+ this year and could become tighter from 3Q as AI projects ramp. E-fabric has the slowest supply response, constrained by longer expansion cycles, loom bottlenecks and technical barriers, giving it the highest pricing leverage.

Investment conclusion — AI PCB upgrade is increasingly an upstream materials story. We see stronger earnings leverage in CCL and e-fabric than PCB, given tighter supply, longer expansion cycles and more direct pricing power. China Jushi remains our preferred China materials beneficiary.

Catalysts/risks — Key catalysts include further CCL price hikes in 2H, stronger Google TPU/Nvidia Rubin/LPU demand, evidence of CCL allocation issues at PCB makers, continued E-fabric price hikes, and China Jushi's potential specialty AI-fabric qualification or batch supply by year-end. **Key risks** include slower AI server ramp, delayed Rubin/TPU/LPU deployment, faster-than-expected new CCL or AI-fabric vendor qualification, weaker general-purpose server demand, and limited cost pass-through in non-AI applications.

What's new?

We discussed the AI PCB supply chain with Karen Huang, Citi's Greater China Technology analyst, who covers A-share PCB names, and Jack Chen, our Taiwan Semiconductors and Components analyst, who covers Taiwan PCB / CCL names. The call focused on three questions:

1. how AI server architecture upgrades are changing PCB specifications.
2. whether CCL and glass cloth supply can keep up with PCB expansion; and
3. which parts of the chain have the strongest pricing power and earnings leverage.

The call reinforces our view that AI-driven PCB demand is becoming more materials-intensive, while upstream supply response remains constrained by long expansion cycles, customer qualification requirements and equipment bottlenecks.

PCB: Tight but not yet in broad shortage

Karen highlighted that AI PCB demand should be viewed through three key end-markets: Nvidia GPU servers, ASIC servers and switches. High-end PCB capacity is tight, but current feedback from covered companies suggests the market has not yet entered a broad-based shortage.

That said, AI accelerator customers are actively securing future supply. Some PCB capacity scheduled for 2H26 and 2027 has already been largely allocated, and certain AI customers are directly reserving entire factory capacity for 2027-28 demand. This suggests the industry is moving toward capacity pre-emption rather than spot shortages.

For Nvidia, the transition from GB300 to Rubin should drive more meaningful PCB upgrades. PCB layer count may rise from around 24 layers to close to 32 layers (switch tray), while copper foil could migrate from HVLP 2/3 to HVLP 4 and glass cloth could move from Low Dk Gen 1 to Low Dk Gen 2 (compute tray). Rubin volume ramp appears somewhat delayed versus earlier market expectations, but PCB demand should lead system shipments by at least one quarter. Karen expects a larger PCB supply-chain transition around 3Q-4Q.

For Google TPU, the upgrade looks more aggressive. TPU V8 could move from 22-24 layers in V7 to 36-44 layers, with material moving from M7 to M8 and glass cloth shifting to Low Dk Gen 2. TPU V9 could further adopt quartz cloth, which would add another layer of material complexity.

ASIC and CPU: New upside to PCB demand

Jack noted that AWS ASIC demand remains strong. For Gold Circuit, Trainium 2 and Trainium 3 show limited changes in area and layer count, remaining around 26 layers, but copper foil is upgrading from Gen 2 to Gen 4. Ramp-up could start soon, with more meaningful volume contribution in 3Q and 4Q.

Trainium 4 is less likely to contribute meaningfully before 2028, as the chip has not yet reached tape-out. Gold Circuit is expanding capacity in Thailand, Taiwan and China to support strong ASIC demand, while it may also start taking Google TPU demand in 4Q per our industry checks.

A key incremental observation from Taiwan GTC / Computex was stronger-than-expected CPU server demand. Jack notes that Vera CPU and traditional x86 server platforms were widely showcased, and downstream component suppliers are increasingly focused on this opportunity. Per our industry checks with Taiwan downstream suppliers, general-purpose server unit shipment growth is estimated at around 20% YoY, while material migration is mainly from M6 to M7 rather than a major increase in PCB layer count.

CCL: Already in supply-constrained territory

Jack believes CCL is already in a supply-constrained environment. Major suppliers including EMC, TUC, Panasonic, Doosan and Shengyi are not adding meaningful capacity this year. He expects Taiwan EMC and TUC to increase output by roughly 20-30%, while Shengyi appears to be in a similar range. Panasonic's and Doosan's meaningful new supply may come mainly next year.

Industry supply growth this year is likely only slightly above 20%, which appears insufficient relative to downstream PCB expansion. While PCB makers believe they have secured 2026-27 supply through forecasts provided to CCL vendors last year, Jack believes the actual CCL supply ramp is lower than PCB capacity expansion. As AI demand ramps in 3Q, some PCB makers may start to face CCL allocation issues.

CCL price hikes are already visible. M7-and-below products have generally seen at least 20% price hikes, while low-end M4 products have increased by around 30-40%. The reason is that CCL makers are actively optimizing product mix and pushing capacity toward M7/M8-and-above products. For AI-related M8 materials, price hikes appear more moderate, likely in the 10-20% range, as CCL vendors still prioritize long-term customer relationships.

Jack believes another round of price hikes is possible in 2H if supply tightens further. If AI customers become more willing to pay premiums to secure CCL supply, CCL vendors could gain stronger pricing power.

Upstream materials: Copper foil and glass cloth could become key bottlenecks

High-end copper foil may become tight as AI demand ramps in 2H, although some CCL vendors still see high-end copper foil pricing as relatively stable for now.

For glass cloth, Low Dk Gen 1 and Low Dk Gen 2 were tight last year due to rapid specification migration, but supply has improved as more vendors in Taiwan and China have joined the market. Current feedback from our industry checks suggests Low Dk Gen 2 is less tight than last year, while Low Dk Gen 1 is also no longer as constrained.

However, conventional E-glass / standard electronic cloth has become tight. This is because many glass cloth producers have shifted capacity from E-glass to higher-margin Low Dk products, while general-purpose server demand has recovered more strongly than expected. As a result, E-glass supply has been structurally squeezed.

Expansion cycle: Supply response remains slow

PCB greenfield expansion generally takes around 13-15 months from land preparation to meaningful revenue recognition, including construction, equipment installation, customer audit and production ramp.

For CCL, brownfield space is limited as existing sites are largely fully loaded. Greenfield projects in China could take around 18 months to reach mass production, while Southeast Asia projects may take around two years due to lower administrative efficiency and less mature ecosystems. Most CCL makers are already planning 2028 greenfield capacity.

For E-fabric, new capacity generally takes around 1.5 years. The bottlenecks include high capex, high technical requirements, long customer qualification cycles and limited loom supply. A 100kt electronic yarn / cloth project may require around Rmb3.7bn investment, three to four times higher than coarse yarn capacity. High-end looms mainly come from Toyota, whose monthly capacity is currently around 200 units and may rise to 300 units by end-2027.

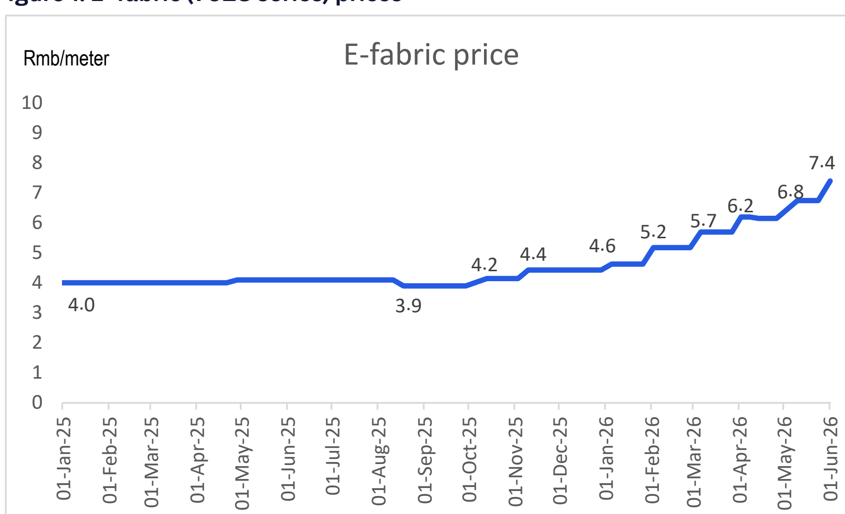
E-fabric: Strongest price momentum in the chain

For China E-fabric, we highlight that conventional E-fabric has seen monthly price hikes from the beginning of the year to June. The latest June price increase widened from Rmb0.3-0.5/m previously to around Rmb0.7/m. Industry participants generally expect price hikes to continue, with supply remaining tight.

The core reason is capacity displacement. High-end special electronic cloth consumes much more loom capacity than standard 7628 cloth. One Toyota loom can produce more than 200k meters of 7628 thick cloth per year, but if used for AI special electronic cloth, output efficiency may fall to around one-quarter. This creates a significant pressure on conventional cloth capacity.

From a tightness perspective, we see Low CTE cloth as the tightest, followed by Low Dk Gen 2, Low Dk Gen 1 and quartz cloth. Quartz cloth capacity is currently the smallest, but demand has not yet ramped meaningfully due to high price and limited mass adoption. Demand could improve in 2H and become more relevant in 2027 with Nvidia LPU and potentially Google TPU V9.

Figure 1. E-fabric (7628 series) prices



Source: Citi Research, SCI

China Jushi: Still our preferred China materials beneficiary

China Jushi remains our preferred name in China materials for this AI PCB material upgrade cycle.

First, the company benefits from volume and price growth. Current electronic cloth capacity is around 960mn meters. The Huai'an 100kt project could add around 390mn meters in two phases, taking total capacity to around 1.35bn meters this year. A further Huai'an project could add another 320mn meters by end-2027.

Second, product mix is upgrading. The company is shifting its electronic cloth mix toward thinner cloth, with thin-cloth share rising from around 15% to 30%. Thin cloth can generate gross margin of 40% or above, which should improve earnings quality even before special AI electronic cloth scales.

Third, special electronic cloth remains a potential re-rating catalyst. China Jushi's special electronic cloth products are still under customer sampling. Management previously indicated a long-term market share target (~15%) for specialty E-fabric products during the 15th Five-Year Plan period.

Based on the current 7628 electronic cloth price of around Rmb7.4/m, China Jushi's unit net profit could be close to Rmb5/m. Full-year earnings could reach around Rmb8.8bn at current pricing, implying around 17.7x PE based on the latest share price as of Jun 9. If prices continue rising in 2H and 7628 price moves above the previous 2021 peak, consensus earnings could potentially revise up, implying cheaper 26E P/E. We believe current valuation still mainly reflects earnings upgrades, not yet a full valuation re-rating.

Investment implications

For A-share PCB, Karen prefers WUS and Delton. WUS benefits from strong technical capability, stable AI customer share and more aggressive capex, while Delton offers higher beta among tier-2 PCB suppliers with overseas AI PCB exposure.

For Taiwan PCB, Jack prefers Gold Circuit and Tripod. Gold Circuit benefits from AWS ASIC and potential Google TPU demand, while Tripod is a cheaper CPU server beneficiary.

For CCL, Jack prefers EMC and TUC, with a preference for EMC, given supply tightness, continued price hikes and product mix upgrade.

For upstream materials, we prefer China Jushi, as e-fabric pricing, capacity expansion, mix upgrade and special cloth qualification could drive both earnings upgrades and potential valuation re-rating.

Key risks

Key risks include slower-than-expected AI server ramp, delays in Rubin / TPU / LPU deployment, slower quartz cloth adoption, faster-than-expected CCL or glass cloth new vendor qualification, weaker general-purpose server demand, limited pass-through in non-AI PCB applications, and slower-than-expected special electronic cloth qualification at China Jushi.

Companies Mentioned:

China Jushi (600176.SS; Rmb39.37; 1; 10 Jun 26; 15:00)

Delton Tech (001389.SZ; Rmb181.4; 1; 10 Jun 26; 15:00)

Elite Material (2383.TW; NT$4940.0; 1; 10 Jun 26; 13:30)

Gold Circuit Electronics (2368.TW; NT$1420.0; 1; 10 Jun 26; 13:30)

Tripod Technology (3044.TW; NT$479.0; 1; 10 Jun 26; 13:30)

TUC (6274.TWO; NT$1500.0; 1; 10 Jun 26; 15:00)

WUS Printed Circuit (002463.SZ; Rmb130.6; 1; 10 Jun 26; 15:00)

If you are visually impaired and would like to speak to a Citi representative regarding the details of the graphics in this document, please call USA 1-888-500-5008 (TTY: 711), from outside the US +1-210-677-3788

Appendix A-1

ANALYST CERTIFICATION

The research analysts primarily responsible for the preparation and content of this research report are either (i) designated by "AC" in the author block or (ii) listed in bold alongside content which is attributable to that analyst. If multiple AC analysts are designated in the author block, each analyst is certifying with respect to the entire research report other than (a) content attributable to another AC certifying analyst listed in bold alongside the content and (b) views expressed solely with respect to a specific issuer which are attributable to another AC certifying analyst identified in the price charts or rating history tables for that issuer shown below. Each of these analysts certify, with respect to the sections of the report for which they are responsible: (1) that the views expressed therein accurately reflect their personal views about each issuer and security referenced and were prepared in an independent manner, including with respect to Citigroup Global Markets Inc. and its affiliates; and (2) no part of the research analyst's compensation was, is, or will be, directly or indirectly, related to the specific recommendations or views expressed by that research analyst in this report.

IMPORTANT DISCLOSURES

Citigroup Global Markets Inc. or its affiliates received compensation for products and services other than investment banking services from China Jushi,Delton Tech,Gold Circuit Electronics,Tripod Technology,WUS Printed Circuit in the past 12 months.

Citigroup Global Markets Inc. or its affiliates currently has, or had within the past 12 months, the following as clients, and the services provided were non-investment-banking, securities-related: China Jushi,Delton Tech,Gold Circuit Electronics,Tripod Technology,WUS Printed Circuit.

Citigroup Global Markets Inc. or its affiliates currently has, or had within the past 12 months, the following as clients, and the services provided were non-investment-banking, non-securities-related: China Jushi,Delton Tech,Gold Circuit Electronics,Tripod Technology,WUS Printed Circuit.

Analysts' compensation is determined by Citi Research management and Citigroup's senior management and is based upon activities and services intended to benefit the investor clients of Citigroup Global Markets Inc. and its affiliates (the "Firm"). Compensation is not linked to specific transactions or recommendations. Like all Firm employees, analysts receive compensation that is impacted by overall Firm profitability which includes investment banking, sales and trading, and principal trading revenues. One factor in equity research analyst compensation is arranging corporate access events between institutional clients and the management teams of covered companies. Typically, company management is more likely to participate when the analyst has a positive view of the company.

For financial instruments recommended in the Product in which the Firm is not a market maker, the Firm is a liquidity provider in such financial instruments (and any underlying instruments) and may act as principal in connection with transactions in such instruments. The Firm is a regular issuer of traded financial instruments linked to securities that may have been recommended in the Product. The Firm regularly trades in the securities of the issuer(s) discussed in the Product. The Firm may engage in securities transactions in a manner inconsistent with the Product and, with respect to securities covered by the Product, will buy or sell from customers on a principal basis.

Unless stated otherwise neither the Research Analyst nor any member of their team has viewed the material operations of the Companies for which an investment view has been provided within the past 12 months.

For important disclosures (including copies of historical disclosures) regarding the companies that are the subject of this Citi Research product ("the Product"), please contact Citi Research, 388 Greenwich Street, 6th Floor, New York, NY, 10013, Attention: Legal/Compliance [E6WYB6412478]. In addition, the same important disclosures, with the exception of the Valuation and Risk assessments and historical disclosures, are contained on the Firm's disclosure website at https://www.citivelocity.com/cvr/eppublic/citi_research_disclosures. Valuation and Risk assessments can be found in the text of the most recent research note/report regarding the subject company. Pursuant to the Market Abuse Regulation a history of all Citi Research recommendations published during the preceding 12-month period can be accessed via Citi Velocity (https://www.citivelocity.com/cv2) or your standard distribution portal. Historical disclosures (for up to the past three years) will be provided upon request.

Citi Research Equity Ratings Distribution

	12 Month Rating			Catalyst Watch		
Data current as of 01 Apr 2026	**Buy**	**Hold**	**Sell**	**Buy**	**Hold**	**Sell**
Citi Research Global Fundamental Coverage (Neutral=Hold)	61%	32%	8%	37%	47%	16%
% of companies in each rating category that are investment banking clients	38%	41%	28%	42%	37%	36%

Guide to Citi Research Fundamental Research Investment Ratings:

Citi Research stock recommendations include an investment rating and an optional risk rating to highlight high risk stocks.

Risk rating takes into account both price volatility and fundamental criteria. Stocks will either have no risk rating or a High risk rating assigned.
Investment Ratings: Citi Research investment ratings are Buy, Neutral and Sell. Our ratings are a function of analyst expectations of expected total return ("ETR") and risk. ETR is the sum of the forecast price appreciation (or depreciation) plus the dividend yield for a stock within the next 12 months. The target price is based on a 12 month time horizon. The Investment rating definitions are: Buy (1) ETR of 15% or more or 25% or more for High risk stocks; and Sell (3) for negative ETR. Any covered stock not assigned a Buy or a Sell is a Neutral (2). For stocks rated Neutral (2), if an analyst believes that there are insufficient valuation drivers and/or investment catalysts to derive a positive or negative investment view, they may elect with the approval of Citi Research management not to assign a target price and, thus, not derive an ETR. Citi Research may suspend its rating and target price and assign “Rating Suspended” status for regulatory and/or internal policy reasons. Citi Research may also suspend its rating and target price and assign "Under Review" status for other exceptional circumstances (e.g. lack of information critical to the analyst's thesis, trading suspension) affecting the company and/or trading in the company's securities. In both such situations, the rating and target price will show as “—“ and “-“ respectively in the rating history price chart. Prior to 11 April 2022 Citi Research assigned “Under Review” status to both situations and prior to 11 Nov 2020 only in exceptional circumstances. As soon as practically possible, the analyst will publish a note re-establishing a rating and investment thesis. Investment ratings are determined by the ranges described above at the time of initiation of coverage, a change in investment and/or risk rating, or a change in target price (subject to limited management discretion). At times, the expected total returns may fall outside of these ranges because of market price movements and/or other short-term volatility or trading patterns. Such interim deviations will be permitted but will become subject to review by Research Management. Your decision to buy or sell a security should be based upon your personal investment objectives and should be made only after evaluating the stock's expected performance and risk.

Catalyst Watch/Short Term Views (“STV”) Ratings Disclosure:
Catalyst Watch and STV Upside/Downside calls: Citi Research may also include a Catalyst Watch or STV Upside or Downside call to indicate the analyst expects the share price to rise (fall) in absolute terms over a specified period of 30 or 90 days in reaction to one or more specific near-term catalysts or events impacting the company or the market. A Catalyst Watch will be published when Analyst confidence is high that an impact to share price will occur; it will be a STV when confidence level is moderate. A Catalyst Watch or STV Upside/Downside call will automatically expire at the end of the specified 30/90 day period. The Catalyst Watch will also be automatically removed if share price performance (calculated at market close) exceeds 15% against the direction of the call (unless over-ridden by the analyst). The analyst may also remove a Catalyst Watch or STV call prior to the end of the specified period in a published research note. A Catalyst Watch/STV Upside or Downside call may be different from and does not affect a stock’s fundamental equity rating, which reflects a longer-term total absolute return expectation. For purposes of FINRA ratings-distribution-disclosure rules, a Catalyst Watch/STV Upside call corresponds to a buy recommendation and a Catalyst Watch/STV Downside call corresponds to a sell recommendation. Any stock not assigned to a Catalyst Watch Upside, Catalyst Watch Downside, STV Upside, or STV Downside call is considered Catalyst Watch/STV No View. For purposes of FINRA ratings distribution-disclosure rules, we correspond Catalyst Watch/STV No View to Hold in our ratings distribution table for our Catalyst Watch/STV Upside/Downside rating system. However, we reiterate that we do not consider No View to be a recommendation. For all Catalyst Watch/STV Upside/Downside calls, risk exists that the catalyst(s) and associated share-price movement will not materialize as expected.

RESEARCH ANALYST AFFILIATIONS / NON-US RESEARCH ANALYST DISCLOSURES
The legal entities employing the authors of this report are listed below (and their regulators are listed further herein). Non-US research analysts who have prepared this report (i.e., all research analysts listed below other than those identified as employed by Citigroup Global Markets Inc.) are not registered/qualified as research analysts with FINRA. Such research analysts may not be associated persons of the member organization (but are employed by an affiliate of the member organization) and therefore may not be subject to the FINRA Rule 2241 restrictions on communications with a subject company, public appearances and trading securities held by a research analyst account.

Citigroup Global Markets Taiwan Securities Company Limited	Jack Chen
Citigroup Global Markets Asia Limited	Anna Wang; Jimmy Feng, CFA; Karen Huang; Jack Shang, CFA; Cynthia Wu

OTHER DISCLOSURES

Any price(s) of instruments mentioned in recommendations are as of the prior day’s market close on the primary market for the instrument, unless otherwise stated.

The completion and first dissemination of any recommendations made within this research report are as of the Eastern date-time displayed at the top of the Product. If the Product references views of other analysts then please refer to the price chart or rating history table for the date/time of completion and first dissemination with respect to that view.

Regulations in various jurisdictions require that where a recommendation differs from any of the author’s previous recommendations concerning the same financial instrument or issuer that has been published during the preceding 12-month period that the change(s) and the date of that previous recommendation are indicated. For fundamental coverage please refer to the price chart or rating change history within this disclosure appendix or the issuer disclosure summary at https://www.citivelocity.com/cvr/eppublic/citi_research_disclosures.

Citi Research has implemented policies for identifying, considering and managing potential conflicts of interest arising as a result of publication or distribution of investment research. A description of these policies can be found at https://www.citivelocity.com/cvr/eppublic/citi_research_disclosures.

The proportion of all Citi Research research recommendations that were the equivalent to "Buy","Hold","Sell" at the end of each quarter over the prior 12 months (with the % of these that had received investment firm services from Citi in the prior 12 months shown in brackets) is as follows; Q1 2026 Buy 33%(63%), Hold 44% (52%), Sell 23% (46%), RV 0.5% (89%): Q4 2025 Buy 33% (63%), Hold 44% (50%), Sell 23% (46%), RV 0.4% (91%); Q3 2025 Buy 33% (61%), Hold 44% (52%), Sell 23% (50%), RV 0.4% (80%); Q2 2025 Buy 33%(63%), Hold 44% (51%), Sell 23% (49%), RV 0.4% (86%). For the purposes of disclosing recommendations other than for equity (whose definitions can be found in the corresponding disclosure sections), "Buy" means a positive directional trade idea; "Sell" means a negative directional trade idea; and "Relative Value" means any trade idea which does not have a clear direction to the investment strategy.

European regulations require a 5 year price history when past performance of a security is referenced. CitiVelocity's Charting Tool (https://www.citivelocity.com/cv2/#go/CHARTING_3_Equities) provides the facility to create customisable price charts including a five year option. This tool can be found in the Data & Analytics section under any of the asset class menus in CitiVelocity (https://www.citivelocity.com/). For further information contact CitiVelocity support (https://www.citivelocity.com/cv2/go/CLIENT_SUPPORT). The source for all referenced prices, unless otherwise stated, is DataCentral, which sources price information from LSEG Data & Analytics. Past performance is not a guarantee or reliable indicator of future results. Forecasts are not a guarantee or reliable indicator of future performance.

Investors should always consider the investment objectives, risks, and charges and expenses of an ETF carefully before investing. The applicable prospectus and key investor information document (as applicable) for an ETF should contain this and other information about such ETF. It is important to read carefully any such prospectus before investing. Clients may obtain prospectuses and key investor information documents for ETFs from the applicable distributor or authorized participant, the exchange upon which an ETF is listed and/or from the applicable website of the applicable ETF issuer. The value of the investments and any accruing income may fall or rise. Any past performance, prediction or forecast is not indicative of future or likely performance. Any information on ETFs contained herein is provided strictly for illustrative purposes and should not be deemed an offer to sell or a solicitation of an offer to purchase units of any ETF either explicitly or implicitly. The opinions expressed are those of the authors and do not necessarily reflect the views of ETF issuers, any of their agents or their affiliates.

Citigroup Global Markets India Private Limited and/or its affiliates may have, from time to time, actual or beneficial ownership of 1% or more in the debt securities of the subject issuer.

Please be advised that pursuant to Executive Order 13959 as amended (the "Order"), U.S. persons are prohibited from investing in securities of any company determined by the United States Government to be the subject of the Order. This research is not intended to be used or relied upon in any way that could result in a violation of the Order. Investors are encouraged to rely upon their own legal counsel for advice on compliance with the Order and other economic sanctions programs administered and enforced by the Office of Foreign Assets Control of the U.S. Treasury Department.

This communication is directed at persons who are "Eligible Clients" as such term is defined in the Israeli Regulation of Investment Advice, Investment Marketing and Investment Portfolio Management law, 1995 (the "Advisory Law"). Within Israel, this communication is not intended for retail clients and Citi will not make such products or transactions available to retail clients or to non-Eligible Clients. The presenter is not licensed as investment advisor or investment marketer by the Israeli Securities Authority ("ISA") and this communication does not constitute investment or marketing advice. The information contained herein may relate to matters that are not regulated by the ISA. Any securities which are the subject of this communication may not be offered or sold to any Israeli person except pursuant to a security offering exemption according to the Israeli Securities Law, 1968and the public offering rules provided thereunder.

Citi Research broadly and simultaneously disseminates its research content to the Firm's institutional and retail clients via the Firm's proprietary electronic distribution platforms (e.g., Citi Velocity and various Global Wealth platforms). As a convenience, certain, but not all, research content may be distributed through third party aggregators. Clients may receive published research reports by email, on a discretionary basis, and only after such research content has been broadly disseminated. Certain research is made available only to institutional investors to satisfy regulatory requirements. The level and types of services provided by Citi Research analysts to clients may vary depending on various factors such as the client's individual preferences as to the frequency and manner of receiving communications from analysts, the client's risk profile and investment focus and perspective (e.g. market-wide, sector specific, long term, short-term etc.), the size and scope of the overall client relationship with the Firm and legal and regulatory constraints.

Pursuant to Comissão de Valores Mobiliários Resolução 20 and ASIC Regulatory Guide 264, Citi is required to disclose whether a Citi related company or business has a commercial relationship with the subject company. Considering that Citi operates multiple businesses in more than 100 countries around the world, it is likely that Citi has a commercial relationship with the subject company.

Securities recommended, offered, or sold by the Firm: (i) are not insured by the Federal Deposit Insurance Corporation; (ii) are not deposits or other obligations of any insured depository institution (including Citibank); and (iii) are subject to investment risks, including the possible loss of the principal amount invested. The Product is for informational purposes only and is not intended as an offer or solicitation for the purchase or sale of a security. Any decision to purchase securities mentioned in the Product must take into account existing public information on such security or any registered prospectus. Although information has been obtained from and is based upon sources that the Firm believes to be reliable, we do not guarantee its accuracy and it may be incomplete and condensed. Note, however, that the Firm has taken all reasonable steps to determine the accuracy and completeness of the disclosures made in the Important Disclosures section of the Product. The Firm's research department has received assistance from the subject company(ies) referred to in this Product including, but not limited to, discussions with management of the subject company(ies). Firm policy prohibits research analysts from sending draft research to subject companies. However, it should be presumed that the author of the Product has had discussions with the subject company to ensure factual accuracy prior to publication. Statements and views concerning ESG (environmental, social, governance) factors are typically based upon public statements made by the affected company or other public news, which the author may not have independently verified. ESG factors are one consideration that investors may choose to examine when making investment decisions. All opinions, projections and estimates constitute the judgment of the author as of the date of the Product and these, plus any other information contained in the Product, are subject to change without notice. Prices and availability of financial instruments also are subject to change without notice. Notwithstanding other departments within the Firm advising the companies discussed in this Product, information obtained in such role is not used in the preparation of the Product. Although Citi Research does not set a predetermined frequency for publication, if the Product is a fundamental equity or credit research report, it is the intention of Citi Research to provide research coverage of the covered issuers, including in response to news affecting the issuer. For non-fundamental research reports, Citi Research may not provide regular updates to the views, recommendations and facts included in the reports. Notwithstanding that Citi Research maintains coverage on, makes recommendations concerning or discusses issuers, Citi Research may be periodically restricted from referencing certain issuers due to legal or policy reasons. Where a component of a published trade idea is subject to a restriction, the trade idea will be removed from any list of open trade ideas included in the Product. Upon the lifting of the restriction, the trade idea will either be re-instated in the open trade ideas list if the analyst continues to support it or it will be officially closed. Citi Research may provide different research products and services to different classes of customers (for example, based upon long-term or short-term investment horizons) that may lead to differing conclusions or recommendations that could impact the price of a security contrary to the recommendations in the alternative research product, provided that each is consistent with the rating system for each respective product.

Investing in non-U.S. securities, including ADRs, may entail certain risks. The securities of non-U.S. issuers may not be registered with, nor be subject to the reporting requirements of the U.S. Securities and Exchange Commission. There may be limited information available on foreign securities. Foreign companies are generally not subject to uniform audit and reporting standards, practices and requirements comparable to those in the U.S. Securities of some foreign companies may be less liquid and their prices more volatile than securities of comparable U.S. companies. In addition, exchange rate movements may have an adverse effect on the value of an investment in a foreign stock and its corresponding dividend payment for U.S. investors. Net dividends to ADR investors are estimated, using withholding tax rates conventions, deemed accurate, but investors are urged to consult their tax advisor for exact dividend computations. Investors who have received the Product from the Firm may be prohibited in certain states or other jurisdictions from purchasing securities mentioned in the Product from the Firm. Please ask your Financial Consultant for additional details. Citigroup Global Markets Inc. takes responsibility for the Product in the United States. Any orders by US investors resulting from the information contained in the Product may be placed only through Citigroup Global Markets Inc.

The Citigroup legal entity that takes responsibility for the production of the Product is the legal entity which the first named author is employed by.

The Product is made available in **Australia** through Citigroup Global Markets Australia Pty Limited. (ABN 64 003 114 832 and AFSL No. 240992), participant of the ASX Group and regulated by the Australian Securities & Investments Commission. Citigroup Centre, 2 Park Street, Sydney, NSW 2000. Citigroup Global Markets Australia Pty Limited is not an Authorised Deposit-Taking Institution under the Banking Act 1959, nor is it regulated by the Australian Prudential Regulation Authority.

The Product is made available in **Brazil** by Citigroup Global Markets Brasil - CCTVM SA, which is regulated by CVM - Comissão de Valores Mobiliários ("CVM"), BACEN - Brazilian Central Bank, APIMEC - Associação dos Analistas e Profissionais de Investimento do Mercado de Capitais and ANBIMA – Associação Brasileira das Entidades dos Mercados Financeiro e de Capitais. Av. Paulista, 1111 - 14º andar(parte) - CEP: 01311920 - São Paulo - SP.

This Product is available in **Chile** through Banchile Corredores de Bolsa S.A., an indirect subsidiary of Citigroup Inc., which is regulated by the Comisión Para El Mercado Financiero. Enrique Foster Sur, 20, piso 6, Las Condes, Santiago, Chile.

Disclosure for investors in the Republic of Colombia :This communication or message does not constitute a professional recommendation to make investment in the terms of article 2.40.1.1.2 of Decree 2555 de 2010 or the regulations that modify, substitute or complement it. Para la elaboración y distribución de informes de investigación y de comunicaciones generales de que trata este artículo no se requiere ser una entidad vigilada por la Superintendencia Financiera de Colombia.

The Product is made available in **Germany** by Citigroup Global Markets Europe AG ("CGME"), which is regulated by the European Central Bank and the German Federal Financial Supervisory Authority (Bundesanstalt fur Finanzdienstleistungsaufsicht BaFin). Börsenplatz 9, 60313 Frankfurt am Main, Germany.

Unless otherwise specified, if the analyst who prepared this report is based in Hong Kong and it relates to “securities” (as defined in the Securities and Futures Ordinance (Cap.571 of the Laws of Hong Kong)), the report is issued in Hong Kong by Citigroup Global Markets Asia Limited. Citigroup Global Markets Asia Limited is regulated by Hong Kong Securities and Futures Commission. If the report is prepared by a non-Hong Kong based analyst, please note that such analyst (and the legal entity that the analyst is employed by or accredited to) is not licensed/registered in Hong Kong and they do not hold themselves out as such. Please refer to the section “Research Analyst Affiliations / Non-US Research Analyst Disclosures” for the details of the employment entity of the analysts.

The Product is made available in **India** by Citigroup Global Markets India Private Limited (CGM), which is regulated by the Securities and Exchange Board of India (SEBI), as a Research Analyst (SEBI Registration No. INH000000438). CGM is also actively involved in the business of merchant banking (SEBI Registration No. INM000010718) and stock brokerage ((SEBI Registration No. INZ000263033) in India, and is registered with SEBI in this regard. Registration granted by SEBI, enlistment with Bombay Stock Exchange (BSE) and certification from National Institute of Securities Markets (NISM) in no way guarantee performance of the intermediary or provide any assurance of returns to investors. CGM's registered office is at 1202, 12th Floor, First International Financial Centre (FIFC), G Block, Bandra Kurla Complex, Bandra East, Mumbai – 400098 & registered Tel: +91 22 61759999. Citi maintains robust policies, procedures,controls, and training to ensure continued compliance with all applicable rulesand regulations. All recommendations contained herein are made by dulyqualified research analysts. CGM's Corporate Identity Number is U99999MH2000PTC126657, and its Compliance Officer [Vishal Bohra] contact details are: Tel:+91-022-61759994, Fax:+91-022-61759851, Email: cgmcompliance@citi.com. The Investor Charter in respect of Research Analysts, the Compliance Audit Report and Complaints information can be found at https://www.citivelocity.com/cvr/eppublic/citi_research_disclosures. The grievance officer [Niraj Mody] contact details are Tel: +91-22-42775002, Email: EMEA.CR.Complaints@citi.com. Investment in securities market are subject to market risks. Read all the related documents carefully before investing. SEBI prescribed Client Terms & Conditions can be found at https://www.citivelocity.com/rendition/authfilelinksvcs/eppublic/V1/file?paramData=ZmlsZU5hbWU9L1MzL0dETVMvcHViRGlzY2xvc3VyZUh0bWxzL2dkbV9kaXNfc2ViaV9UZXJtc29mVXNlLmh0bWw

The Product is made available in **Indonesia** through PT Citigroup Sekuritas Indonesia. Citibank Tower 10/F, Pacific Century Place, SCBD lot 10, Jl. Jend Sudirman Kav 52-53, Jakarta 12190, Indonesia. Neither this Product nor any copy hereof may be distributed in Indonesia or to any Indonesian citizens wherever they are domiciled or to Indonesian residents except in compliance with applicable capital market laws and regulations. This Product is not an offer of securities in Indonesia. The securities referred to in this Product have not been registered with the Capital Market and Financial Services Authority (OJK) pursuant to relevant capital market laws and regulations, and may not be offered or sold within the territory of the Republic of Indonesia or to Indonesian citizens through a public offering or in circumstances which constitute an offer within the meaning of the Indonesian capital market laws and regulations.

The Product is made available in **Japan** by Citigroup Global Markets Japan Inc. ("CGMJ"), which is regulated by Financial Services Agency, Securities and Exchange Surveillance Commission, Japan Securities Dealers Association, Tokyo Stock Exchange and Osaka Securities Exchange. Otemachi Park Building, 1-1-1 Otemachi, Chiyoda-ku, Tokyo 100-8132 Japan. In the event that an error is found in an CGMJ research report, a revised version will be posted on the Firm's Citi Velocity website. If you have questions regarding Citi Velocity, please call (81 3) 6270-3019 for help.

The product is made available in the **Kingdom of Saudi Arabia** in accordance with Saudi laws through Citigroup Saudi Arabia, which is regulated by the Capital Market Authority (CMA) under CMA license (17184-31). 2239 Al Urubah Rd – Al Olaya Dist. Unit No. 18, Riyadh 12214 – 9597, Kingdom Of Saudi Arabia.

The Product is made available in **Korea** by Citigroup Global Markets Korea Securities Ltd. (CGMK), which is regulated by the Financial Services Commission, the Financial Supervisory Service and the Korea Financial Investment Association (KOFIA). The address of CGMK is Citibank Center, 50 Saemunan-ro, Jongno-gu, Seoul 03184, Korea. KOFIA makes available registration information of research analysts on its website. Please visit the following website if you wish to find KOFIA registration information on research analysts of CGMK. http://dis.kofia.or.kr/websquare/index.jsp?w2xPath=/wq/fundMgr/DISFundMgrAnalystList.xml&divisionId=MDIS03002002000000&serviceId=SDIS03002002000. The Product is made available in Korea by Citibank Korea Inc., which is regulated by the Financial Services Commission and the Financial Supervisory Service. Address is Citibank Center, 50 Saemunan-ro, Jongno-gu, Seoul 03184, Korea. This research report is intended to be provided only to Professional Investors as defined in the Financial Investment Services and Capital Market Act and its Enforcement Decree in Korea.

The Product is made available in **Malaysia** by Citigroup Global Markets Malaysia Sdn Bhd (Registration No. 199801004692 (460819-D)) ("CGMM") to its clients and CGMM takes responsibility for its contents as regards CGMM's clients. CGMM is regulated by the Securities Commission Malaysia. Please contact CGMM at Level 43 Menara Citibank, 165 Jalan Ampang, 50450 Kuala Lumpur, Malaysia in respect of any matters arising from, or in connection with, the Product.

The Product is made available in **Mexico** by Citi México Casa de Bolsa, S.A. de C.V., Grupo Financiero Citi México which is a wholly owned subsidiary of Citigroup Inc. and is regulated by Comision Nacional Bancaria y de Valores. Prolongación Reforma 1196, 24 floor, Colonia Santa Fe, Alcaldía Cuajimalpa de Morelos, C.P. 05348, Ciudad de México.

The Product is made available in **Poland** by Biuro Maklerskie Banku Handlowego (DMBH), separate department of Bank Handlowy w Warszawie S.A. a subsidiary of Citigroup Inc., which is regulated by Komisja Nadzoru Finansowego. Biuro Maklerskie Banku Handlowego (DMBH), ul.Senatorska 16, 00-923 Warszawa.

The Product is made available in **Singapore** through Citigroup Global Markets Singapore Pte. Ltd. ("CGMSPL"), a capital markets services and Exempt Financial Advisor license holder, and regulated by Monetary Authority of Singapore. Please contact CGMSPL at 8 Marina View, 21st Floor Asia Square Tower 1, Singapore 018960, in respect of any matters arising from, or in connection with, the analysis of this document. This Product is intended for recipients who are accredited, expert and institutional investors as defined under the Securities and Futures Act 2001. For Citi Private Bank, the Product is made available in Singapore by Citi Private Bank through Citibank, N.A., Singapore Branch. Citibank N.A., Singapore Branch is a licensed bank in Singapore that is regulated by the Monetary Authority of Singapore. Please contact your Private Banker in Citibank N.A., Singapore Branch if you have any queries on or any matters arising from or in connection with this document. The Product is intended for recipients who are accredited, expert and institutional investors as defined under the Securities and Futures Act 2001. For Citibank Singapore Limited (“CSL”), the Product is distributed in Singapore by CSL to selected Citigold/Citigold Private Clients. CSL provides no independent research or analysis of the substance or in preparation of the Product. Please contact your Citigold//Citigold Private Client Relationship Manager in CSL if you have any queries on or any matters arising from or in connection with this document. The Product is intended for recipients who are accredited investors as defined under the Securities and Futures Act (Cap. 289).

Citigroup Global Markets (Pty) Ltd. is incorporated in the **Republic of South Africa** (company registration number 2000/025866/07) and its registered office is at 145 West Street, Sandton, 2196, Saxonwold. Citigroup Global Markets (Pty) Ltd. is regulated by JSE Securities Exchange South Africa, South African Reserve Bank and the Financial Services Board. The investments and services contained herein are not available to private customers in South Africa.

The Product is made available in the **Republic of China (Taiwan)** through Citigroup Global Markets Taiwan Securities Company Ltd. ("CGMTS"), 14F, 15F and 16F, No. 1, Songzhi Road, Taipei 110, Taiwan, subject to the license scope and the applicable laws and regulations in the Republic of China (Taiwan). CGMTS is regulated by the Securities and Futures Bureau of the Financial Supervisory Commission of Taiwan, the Republic of China (Taiwan). No portion of the Product may be reproduced or quoted in the Republic of China (Taiwan) by the press or any third parties [without the written authorization of CGMTS]. Pursuant to the applicable laws and regulations in the Republic of China (Taiwan), the recipient of the Product shall not take advantage of such Product to involve in any matters in which the recipient may have conflicts of interest. If the Product covers securities which are not allowed to be offered or traded in the Republic of China (Taiwan), neither the Product nor any information contained in the Product shall be considered as advertising the securities or making recommendation of the securities in the Republic of China (Taiwan). The Product is for informational purposes only and is not intended as an offer or solicitation for the purchase or sale of a security or financial products. Any decision to purchase securities or financial products mentioned in the Product must take into account existing public information on such security or the financial products or any registered prospectus.

The Product is made available in **Thailand** through Citicorp Securities (Thailand) Ltd., which is regulated by the Securities and Exchange Commission of Thailand. 399 Interchange 21 Building, 18th Floor, Sukhumvit Road, Klongtoey Nua, Wattana ,Bangkok 10110, Thailand.

Disclosure for investors in the Republic of Turkey: The Product is made available in **Turkey** through Citibank AS which is regulated by Capital Markets Board. Tekfen Tower, Eski Buyukdere Caddesi # 209 Kat 2B, 23294 Levent, Istanbul, Turkey. Under Capital Markets Law of Turkey (Law No: 6362), the investment information, comments and recommendations stated here, are not within the scope of investment advisory activity. Comments and recommendations stated here rely on the individual opinions of the ones providing these comments and recommendations. These opinions may not fit to your financial status, risk and return preferences. For this reason, to make an investment decision by relying solely to this information stated here may not bring about outcomes that fit your expectations. Furthermore, Citi Research is a division of Citigroup Global Markets Inc. (the “Firm”), which does and seeks to do business with companies and/or trades on securities covered in this research reports. As a result, investors should be aware that the Firm may have a conflict of interest that could affect the objectivity of this report, however investors should also note that the Firm has in place organisational and administrative arrangements to manage potential conflicts of interest of this nature.

In the **U.A.E**, these materials (the "Materials") are communicated byCitigroup Global Markets Limited, DIFC branch ("CGML"), an entityregistered in the Dubai International Financial Center ("DIFC") andlicensed and regulated by the Dubai Financial Services Authority ("DFSA",license #CL0221) to Professional Clients and Market Counterparties, as definedin DFSA regulations, only and should not be relied upon or distributed toRetail Clients. Financial products and/or services to which the Materialsrelate will only be made available to Professional Clients and MarketCounterparties. Citigroup Global Markets Limited DIFC Branch registered addressis Level 3, Gate District Building 02, Dubai International Financial Centre andcan be contacted on +971 4 509 97 90.

The Product is made available in **United Kingdom** by Citigroup Global Markets Limited, which is authorised by the Prudential Regulation Authority (“PRA”) and regulated by the Financial Conduct Authority (“FCA”) and the PRA. This material may relate to investments or services of a person outside of the UK or to other matters which are not authorised by the PRA nor regulated by the FCA and the PRA and further details as to where this may be the case are available upon request in respect of this material. Citigroup Centre, Canada Square, Canary Wharf, London, E14 5LB.

The Product is made available in **United States** and **Canada** by Citigroup Global Markets Inc., which is a member of FINRA and registered with the US Securities and Exchange Commission. 388 Greenwich Street, New York, NY 10013.

Unless specified to the contrary, within EU Member States, the Product is made available by Citigroup Global Markets Europe AG ("CGME"), which is regulated by the European Central Bank and the German Federal Financial Supervisory Authority (Bundesanstalt für Finanzdienstleistungsaufsicht-BaFin).

The Product is not to be construed as providing investment services in any jurisdiction where the provision of such services would not be permitted.

Subject to the nature and contents of the Product, the investments described therein are subject to fluctuations in price and/or value and investors may get back less than originally invested. Certain high-volatility investments can be subject to sudden and large falls in value that could equal or exceed the amount invested.The yield and average life of CMOs (collateralized mortgage obligations) referenced in this Product will fluctuate depending on the actual rate at which mortgage holders prepay the mortgages underlying the CMO and changes in current interest rates. Any government agency backing of the CMO applies only to the face value of the CMO and not to any premium paid. Certain investments contained in the Product may have tax implications for private customers whereby levels and basis of taxation may be subject to change. If in doubt,