CME Group

CME Group Volatility Index (CVOL^{tm}) Live Streaming Calculation Guide

CME Group Benchmark Administration Limited

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1. Live Streaming CVOL Overview

The Live Streaming CVOL Indices provide an intra-day view of implied volatility across five different asset classes, derived from the world's most actively traded options on futures. Live Streaming CVOLs provide a measure of the market's expectation of forward risk, calculated every 15 seconds throughout the day, along with associated derivative indicators.

Single Product Live Streaming CVOL Indices

Foreign Exchange – Single Product							
Contract	**CVOL Group**	**CVOL Symbol**	**UpVar Symbol**	**DownVar Symbol**	**Skew Symbol**	**ATM Vol Symbol**	**Convexity Symbol**
EUR/USD (EUU)	Tenor Selection 4	CVOL:EUVL	UPVAR:EUVL	DNVAR:EUVL	SKEW:EUVL	ATMVOL:EUVL	CONVEX:EUVL
GBP/USD (GBU)	Tenor Selection 4	CVOL:GBVL	UPVAR:GBVL	DNVAR:GBVL	SKEW:GBVL	ATMVOL:GBVL	CONVEX:GBVL
JPY/USD (JPU)	Tenor Selection 4	CVOL:JPVL	UPVAR:JPVL	DNVAR:JPVL	SKEW:JPVL	ATMVOL:JPVL	CONVEX:JPVL
AUD/USD (AUU)	Tenor Selection 4	CVOL:ADVL	UPVAR:ADVL	DNVAR:ADVL	SKEW:ADVL	ATMVOL:ADVL	CONVEX:ADVL
CAD/USD (CAU)	Tenor Selection 4	CVOL:CAVL	UPVAR:CAVL	DNVAR:CAVL	SKEW:CAVL	ATMVOL:CAVL	CONVEX:CAVL

Metals – Single Product							
Contract	**CVOL Group**	**CVOL Symbol**	**UpVar Symbol**	**DownVar Symbol**	**Skew Symbol**	**ATM Vol Symbol**	**Convexity Symbol**
Silver (SO)	Tenor Selection 4	CVOL:SIVL	UPVAR:SIVL	DNVAR:SIVL	SKEW: SIVL	ATMVOL:SIVL	CONVEX:SIVL
Gold (OG)	Tenor Selection 4	CVOL:GCVL	UPVAR:GCVL	DNVAR:GCVL	SKEW:GCVL	ATMVOL:GCVL	CONVEX:GCVL
Copper (HXE)	Tenor Selection 2	CVOL:HGVL	UPVAR:HGVL	DNVAR:HGVL	SKEW:HGVL	ATMVOL:HGVL	CONVEX:HGVL
Platinum (PO)	Tenor Selection 2	CVOL:POVL	UPVAR:POUP	DNVAR:PODN	SKEW:POSK	ATMVOL:POAM	CONVEX:POCV

Energy – Single Product							
Contract	**CVOL Group**	**CVOL Symbol**	**UpVar Symbol**	**DownVar Symbol**	**Skew Symbol**	**ATM Vol Symbol**	**Convexity Symbol**
WTI Crude Oil (LO)	Tenor Selection 2	CVOL:CLVL	UPVAR:CLVL	DNVAR:CLVL	SKEW:CLVL	ATMVOL:CLVL	CONVEX:CLVL
Henry Hub Natural Gas (LN)	Tenor Selection 2	CVOL:NGVL	UPVAR:NGVL	DNVAR:NGVL	SKEW:NGVL	ATMVOL:NGVL	CONVEX:NGVL
NY Harbor ULSD(OH)	Tenor Selection 2	CVOL:HOVL	UPVAR:HOVL	DNVAR:HOVL	SKEW:HOVL	ATMVOL:HOVL	CONVEX:HOVL

Interest Rate – Single Product							
Contract	**CVOL Group**	**CVOL Symbol**	**UpVar Symbol**	**DownVar Symbol**	**Skew Symbol**	**ATM Vol Symbol**	**Convexity Symbol**
SOFR-SR3 90-day	Tenor Selection 7 (90 DTE)	CVOL:SRVL	UPVAR:SRVL	DNVAR:SRVL	SKEW:SRVL	ATMVOL:SRVL	CONVEX:SRVL
SR3 1-year Midcurve 90-day	Tenor Selection 7 (90 DTE)	CVOL:S1VL	UPVAR:S1VL	DNVAR:S1VL	SKEW:S1VL	ATMVOL:S1VL	CONVEX:S1VL
SR3 2-year Midcurve 90-day	Tenor Selection 7 (90 DTE)	CVOL:S2VL	UPVAR:S2VL	DNVAR:S2VL	SKEW:S2VL	ATMVOL:S2VL	CONVEX:S2VL
US 2-year T-Note (OZT) - Price	Tenor Selection 2	CVOL:TUVL	UPVAR:TUVL	DNVAR:TUVL	SKEW:TUVL	ATMVOL:TUVL	CONVEX:TUVL
US 2-year T-Note (OZT) - Yield	Tenor Selection 2	CVOL:TUVY	UPVAR:TUVY	DNVAR:TUVY	SKEW:TUVY	ATMVOL:TUVY	CONVEX:TUVY
US 5-year T-Note (OZF) - Price	Tenor Selection 4	CVOL:FVVL	UPVAR:FVVL	DNVAR:FVVL	SKEW:FVVL	ATMVOL:FVVL	CONVEX:FVVL
US 5-year T-Note (OZF) - Yield	Tenor Selection 4	CVOL:FVVY	UPVAR:FVVY	DNVAR:FVVY	SKEW:FVVY	ATMVOL:FVVY	CONVEX:FVVY
US 10-year T-Note (OZN) - Price	Tenor Selection 4	CVOL:TYVL	UPVAR:TYVL	DNVAR:TYVL	SKEW:TYVL	ATMVOL:TYVL	CONVEX:TYVL
US 10-year T-Note (OZN) - Yield	Tenor Selection 4	CVOL:TYVY	UPVAR:TYVY	DNVAR:TYVY	SKEW:TYVY	ATMVOL:TYVY	CONVEX:TYVY
US 30-year T-Bond (OZB) - Price	Tenor Selection 4	CVOL:USVL	UPVAR:USVL	DNVAR:USVL	SKEW:USVL	ATMVOL:USVL	CONVEX:USVL
US 30-year T-Bond (OZB) - Yield	Tenor Selection 4	CVOL:USVY	UPVAR:USVY	DNVAR:USVY	SKEW:USVY	ATMVOL:USVY	CONVEX:USVY

Agriculture – Single Product							
Contract	**CVOL Group**	**CVOL Symbol**	**UpVar Symbol**	**DownVar Symbol**	**Skew Symbol**	**ATM Vol Symbol**	**Convexity Symbol**
Wheat (OZW)	Tenor Selection 2	CVOL:WVL	UPVAR:WVL	DNVAR:WVL	SKEW:WVL	ATMVOL:WVL	CONVEX:WVL
Corn (OZC)	Tenor Selection 2	CVOL:CVL	UPVAR:CVL	DNVAR:CVL	SKEW:CVL	ATMVOL:CVL	CONVEX:CVL
Soybean (OZS)	Tenor Selection 2	CVOL:SVL	UPVAR:SVL	DNVAR:SVL	SKEW:SVL	ATMVOL:SVL	CONVEX:SVL
Soybean Oil (OZL)	Tenor Selection 2	CVOL:SOVL	UPVAR:SOVL	DNVAR:SOVL	SKEW:SOVL	ATMVOL:SOVL	CONVEX:SOVL
Soybean Meal (OZM)	Tenor Selection 2	CVOL:SMVL	UPVAR:SMVL	DNVAR:SMVL	SKEW:SMVL	ATMVOL:SMVL	CONVEX:SMVL
Lean Hogs (HE)	Tenor Selection 6 (60DTE)	CVOL:HEVL	UPVAR:HEVL	DNVAR:HEVL	SKEW:HEVL	ATMVOL:HEVL	CONVEX:HEVL
Live Cattle (LE)	Tenor Selection 6(60DTE)	CVOL:LEVL	UPVAR:LEVL	DNVAR:LEVL	SKEW:LEVL	ATMVOL:LEVL	CONVEX:LEVL
Class III Milk (DC)	Tenor Selection 6(60DTE)	CVOL:DCVL	UPVAR:DCVL	DNVAR:DCVL	SKEW:DCVL	ATMVOL:DCVL	CONVEX:DCVL
Feeder Cattle (GF)	Tenor Selection 6(60DTE)	CVOL:GFVL	UPVAR:GFVL	DNVAR:GFVL	SKEW:GFVL	ATMVOL:GFVL	CONVEX:GFVL

Broad Based Live Streaming CVOL Indices

Foreign Exchange – Broad Based						
Name	**CVOL Symbol**	**UpVar Symbol**	**DownVar Symbol**	**Skew Symbol**	**ATM Vol Symbol**	**Convexity Symbol**
FX G5 Volatility Index (EUVL, GBVL, JPVL, ADVL, CAVL)	CVOL:FXVL	UPVAR:FXVL	DNVAR:FXVL	SKEW:FXVL	ATMVOL:FXVL	CONVEX:FXVL

Interest Rate – Broad Based						
Name	**CVOL Symbol**	**UpVar Symbol**	**DownVar Symbol**	**Skew Symbol**	**ATM Vol Symbol**	**Convexity Symbol**
Treasury Curve Volatility Index - Price (TUVL, FVVL, TYVL, USVL)	CVOL:TPVL	UPVAR:TPVL	DNVAR:TPVL	SKEW:TPVL	ATMVOL:TPVL	CONVEX:TPVL
Treasury Curve Volatility Index - Yield (TUVY, FVVY, TYVY, USVY)	CVOL:TVL	UPVAR:TVL	DNVAR:TVL	SKEW:TVL	ATMVOL:TVL	CONVEX:TVL

Metals – Broad Based						
Name	**CVOL Symbol**	**UpVar Symbol**	**DownVar Symbol**	**Skew Symbol**	**ATM Vol Symbol**	**Convexity Symbol**
Metals Volatility Index (SIVL, GCVL, HGVL, POVL)	CVOL:MVL	UPVAR:MVL	DNVAR:MVL	SKEW:MVL	ATMVOL:MVL	CONVEX:MVL

Energy – Broad Based						
Name	**CVOL Symbol**	**UpVar Symbol**	**DownVar Symbol**	**Skew Symbol**	**ATM Vol Symbol**	**Convexity Symbol**
Energy Volatility Index (CLVL, NGVL, HOVL)	CVOL:EVL	UPVAR:EVL	DNVAR:EVL	SKEW:EVL	ATMVOL:EVL	CONVEX:EVL

Agriculture – Broad Based						
Name	**CVOL Symbol**	**UpVar Symbol**	**DownVar Symbol**	**Skew Symbol**	**ATM Vol Symbol**	**Convexity Symbol**
Agriculture Volatility Index (WVL, CVL, SVL, SOVL, SMVL, HEVL, LEVL, DCVL, GFVL)	CVOL:AVL	UPVAR:AVL	DNVAR:AVL	SKEW:AVL	ATMVOL:AVL	CONVEX:AVL

Commodity – Broad Based						
Name	**CVOL Symbol**	**UpVar Symbol**	**DownVar Symbol**	**Skew Symbol**	**ATM Vol Symbol**	**Convexity Symbol**
Commodity Volatility Index (CLVL, NGVL, HOVL, WVL, CVL, SVL, SIVL, GCVL, HGVL, LEVL, HEVL, DCVL)	CVOL:CMVL	UPVAR:CMVL	DNVAR:CMVL	SKEW:CMVL	ATMVOL:CMVL	CONVEX:CMVL

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2. Product Calculation Windows

The following table outlines the periods of time (shown below in Eastern Standard Time) for which calculations will be performed for each Live Streaming CVOL index. Note that when a time is indicated as t-1, it begins the evening of the prior day, with that overnight session combined with the day session as a single calculation period.

Single Product Live Streaming CVOL Indices

Product	CVOL	Group	Start	End	Preliminary Settlement Time
DC	DCVL	Ags	10:00 AM ET	2:00 PM ET	2:00 PM ET
OZW	WVL	Ags	2:00 AM ET	2:15 PM ET	2:15 PM ET
OZS	SVL	Ags	2:00 AM ET	2:15 PM ET	2:15 PM ET
LE	LEVL	Ags	9:30 AM ET	2:00 PM ET	2:00 PM ET
OZM	SMVL	Ags	2:00 AM ET	2:15 PM ET	2:15 PM ET
OZL	SOVL	Ags	2:00 AM ET	2:15 PM ET	2:15 PM ET
OZC	CVL	Ags	2:00 AM ET	2:15 PM ET	2:15 PM ET
HE	HEVL	Ags	9:30 AM ET	2:00 PM ET	2:00 PM ET
GF	GFVL	Ags	10:00 AM ET	2:00 PM ET	2:00 PM ET
TU	TUVL/TUVY	Interest Rate	8:00 AM ET	4:45 PM ET	3:00 PM ET
FV	FVVL/FVVY	Interest Rate	8:00 AM ET	4:45 PM ET	3:00 PM ET
TY	TYVL/TYVY	Interest Rate	10:30 PM ET (t-1)	4:45 PM ET	3:00 PM ET
US	USVL/USVY	Interest Rate	8:00 AM ET	4:45 PM ET	3:00 PM ET
SR3	SRVL	Interest Rate	2:00 AM ET	4:45 PM ET	3:00 PM ET
S0	S1VL	Interest Rate	2:00 AM ET	4:45 PM ET	3:00 PM ET
S2	S2VL	Interest Rate	2:00 AM ET	4:45 PM ET	3:00 PM ET
ADU	ADVL	FX	1:30 AM ET	4:00 PM ET	3:00 PM ET
CAU	CAVL	FX	1:30 AM ET	4:00 PM ET	3:00 PM ET
EUU	EUVL	FX	1:30 AM ET	4:00 PM ET	3:00 PM ET
GBU	GBVL	FX	1:30 AM ET	4:00 PM ET	3:00 PM ET
JPU	JPVL	FX	1:30 AM ET	4:00 PM ET	3:00 PM ET
OG	GCVL	Metals	10:30 PM ET (t-1)	4:45 PM ET	1:30 PM ET
SO	SIVL	Metals	10:30 PM ET (t-1)	4:45 PM ET	1:25 PM ET
HXE	HGVL	Metals	10:30 PM ET (t-1)	4:45 PM ET	1:00 PM ET
PO	POVL	Metals	4:00 AM ET	4:45 PM ET	2:15 PM ET
LO	CLVL	Energy	10:30 PM ET (t-1)	4:45 PM ET	2:30 PM ET
LN	NGVL	Energy	10:30 PM ET (t-1)	4:45 PM ET	2:30 PM ET
OH	HOVL	Energy	10:00 AM ET	4:45 PM ET	2:30 PM ET

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Broad Based Live Streaming CVOL Indices

Product	CVOL	Group	Start	End	Preliminary Settlement Time
AGVL	AGVL	Ags	10:00 AM ET	2:00 PM ET	2:00 PM ET
TVL	TVL	Interest Rate	8:00 AM ET	4:45 PM ET	3:00 PM ET
TPVL	TPVL	Interest Rate	8:00 AM ET	4:45 PM ET	3:00 PM ET
FXVL	FXVL	FX (G5)	1:30 AM ET	4:00 PM ET	3:00 PM ET
MVL	MVL	Metals	4:00 AM ET	4:45 PM ET	1:30 PM ET
EVL	EVL	Energy	10:00 AM ET	4:45 PM ET	2:30 PM ET
CMVL	CMVL	Commodity	10:00 AM ET	4:45 PM ET	2:00 PM ET

3. Input Data

The calculation of the Live Streaming CVOL single product indices uses the following data:

- The current UTC wall clock time t
- Time (in milliseconds) to Expiration for selected Tenor(s) $T_1, T_2 \ldots T_N$
- The target time horizon of the volatility index: T_H
- The Future bid and ask for each tenor N (used to calculate the Future mid, F_N)
- The minimum price increment of the product z
- For Selected Option Expiration, T_N, the vector of all listed strikes, K_i
- For each strike, K_i, live Bid and Ask data for both Calls and Puts:
    - Call Asks and Bids: CA_i, CB_i
    - Put Asks and Bids: PA_i, PB_i
- Discounting SOFR interest rate curve with continuous integer offsets as made available on the previous business day relative to the current calculation day
- Metrics from the previous calculation at $t - 1$:
    - The ATM vol of the previous calculation: ATM_{t-1}
    - The CVOL calculation of the previous calculation: $CVol_{t-1}$
    - The Skew of the previous calculation: $Skew_{t-1}$
    - The total number of strikes by tenor used in the calculation after all filtering processes are completed: $\#K_{t-1_N}$
    - The strike that represents the first Out-of-the-Money (OTM) Put in the prior period for tenor N: K_{Seed_N}
- For Broad Based Indices (i.e. CVOL indices with more than one product making its composition), the following additional data is required:
    - The vega calculated for each strike of all outstanding options for a given product
    - The open interest for each strike of all outstanding options for a given product
    - The Contract Money Multiplier for a given product

- For CVOL indices calculated in yield space, the additional data is required:
  - The DV01 for a given tenor: $DV01_N$

3.1. Determining the Discount Rate

The Discount Rate is arrived at through a two-step process: (1) selection of the SOFR rate from the curve from the previous day's End-of-Day fully interpolated curve and (2) calculation of the instantaneous rate to account for time passed during the calculation session.

1. The SOFR rate applied to a given contract is determined prior to the start of the calculation session. $R_{N_{EOD}}$ is determined by taking the previous End-of-Day SOFR Discount Curve and designating the integer value for the selected tenors which is closest to but greater than the days to maturity.
2. To arrive at the instantaneous rate, the following formula is used:

$$G_N = \exp exp\left(\frac{\ln ln\left(R_{N_{EOD}}\right)}{\frac{T_{N_{EOD}}}{T_N}}\right)$$

Where:

- $R_{N_{EOD}}$ is the EOD SOFR rate queried that corresponds to the given tenor N for the given calculation session
- T_N is the Days To Expiry (DTE) of tenor T_N as expressed in milliseconds
- $T_{N_{EOD}}$ is the DTE of the EOD SOFR rate $R_{N_{EOD}}$

4. Calculation Process

The following outlines the process to perform a Live Streaming CVOL calculation, including when reprint logic is invoked.

4.1. Determining the futures contract price

The synthetic futures contract price for the Live Streaming CVOL calculation is determined as follows:

- The strike K is determined as the strike for $Min\left(\left|K - K_{seed_N}\right|\right)$ where:
  - $CA_K \neq 0$
  - $CB_K \neq 0$
  - $PA_K \neq 0$
  - $PB_K \neq 0$
- Strike K is used to determine the synthetic future:

$$F_{synth} = K + 0.5 * \left(CA_K + CB_K\right) - 0.5 * \left(PA_K + PB_K\right)$$

This value is compared against the value of the mid of the underlying Future ($F_{underlying}$) bid and ask. The value of the future F_N is determined as:

- If either the bid or ask of the underlying Future is not available but F_{synth} can be calculated, $F_{synth} = F_N$
- If F_{synth} is not calculable and $F_{underlying}$ can be calculated, $F_{underlying} = F_N$
- If $\left|F_{synth} - F_{underlying}\right| > 4z$, where z is the minimum option price tick, then $F_{synth} = F_N$

4.2. Determining the set of strikes to be included in the calculation

Once F_N is determined, the following filtering is applied to all Out-of-the-Money (OTM) options:

- All strikes whose Ask value is zero (CA_K, $PA_K = 0$) are removed
- If the sum of three consecutive Call bids is zero (i.e. $CB_{K_i} + CB_{K_{i+1}} + CB_{K_{i+2}} = 0$, where K_i is the closest strike of the three to F_N), then ignore K_i and all records above K_i
- If the sum of three consecutive Put bids is zero (i.e. $PB_{K_i} + PB_{K_{i-1}} + PB_{K_{i-2}} = 0$ where K_i is the closest strike of the three to F_N), then ignore K_i and all records below K_i
- Of the remaining strikes, all strikes whose Bid value is zero (CB_K, $PA_K = 0$) are removed.

4.3. ATM Volatility Calculation

Perform the ATM calculation for each tenor N and for the timeweighted ATM value by following the steps and formulae below:

- Determine the ATM option premium where F_N is not an existing strike:

$$O_{0_N} = \frac{0.5*\left(F-K_{-1}\right)*\left(C_{K+1}+P_{K+1}\right)+0.5*\left(K_{+1}-F\right)*\left(P_{K-1}+C_{K-1}\right)}{K_{+1}-K_{-1}}$$

Where:

O_{0_N} = the ATM option premium calculation for tenor N

K_{+1} = the strike above F as defined in 'Determining the Strike Closest to the Money' section

$C_{K_{+1}}$ = the call premium of strike K_{+1}, with the premium being the mid of the bid and offer

$C_{K_{-1}}$ = the call premium of strike K_{-1}, with the premium being the mid of the bid and offer

$P_{K_{+1}}$ = the call premium of strike K_{+1}, with the premium being the mid of the bid and offer

$P_{K_{-1}}$ = the call premium of strike K_{-1}, with the premium being the mid of the bid and offer

- Determine the ATM option premium where F_N is an existing:

$$O_{0_N} = 0.5 * \left(C_{K_0} + P_{K_0}\right)$$

Where:

O_{0_N} = the ATM option premium calculation for tenor N

K_0 = the strike equal to F

C_{K_0} = the call premium of strike K_0, with the premium being the mid of the bid and offer

P_{K_0} = the call premium of strike K_0, with the premium being the mid of the bid and offer

- Determine the ATM volatility of tenor N:

$$ATM_N = 100\sqrt{\frac{2\pi}{T_N}} * \frac{O_{0_N}}{F_N}$$

4.4. ATM Variance Adjustment

Calculate Delta K: The value of Delta K (ΔK) for each strike is determined by the following rules:

- If the option is the highest struck Call: $\Delta K = K_i - K_{i-1}$
- If the option is the lowest struck Put: $\Delta K = K_{i+1} - K_i$
- If the option is a Call at the strike where $K_i = F_N$: $\Delta K = (K_1 - F)/2$
- If the option is a Put at the strike where $K_i = F_N$: $\Delta K = (F - K_{-1})/2$
- Otherwise: $\Delta K = (K_{i+1} - K_{i-1})/2$

ATM Adjustment: VA_0 is defined as the variance area as below:

$$VA_0 = \Delta K_0 * O_0$$

Where:

- If the closest strike to ATM is below F, $\Delta K_0 = \frac{K_{-1}+K_{+1}}{2} - F$
- If the closest strike to ATM is above F, $\Delta K_0 = F - \frac{K_{-1}+K_{+1}}{2}$

- If there is a strike that is exactly ATM, ΔK is already determined
- If F is a mid-point between K_{-1} and K_{+1}, no adjustment is needed as $\Delta K = 0$
- K_{-1} is the closest to the money Put strike
- K_{+1} is the closest to the money Call strike

With VA_0 calculated, the Variance Area adjustments for the Put $\left(adjVA_{-1}\right)$ and Call $\left(adjVA_{+1}\right)$ wings are formulated below for the following scenarios:

- In the instance where the closest strike to ATM is below F, the calculated VA_0 is:

$$adjVA_{-1} = VA_{-1} - VA_0$$
$$adjVA_{+1} = VA_{-1} + VA_0$$

- In the instance where the closest strike to ATM is above F, the calculated VA_0 is:

$$adjVA_{-1} = VA_{-1} + VA_0$$
$$adjVA_{+1} = VA_{-1} - VA_0$$

- In the instance where there is a strike exactly equal to F or F is a midpoint between K_{-1}, K_{+1}, then $adjVA_{+1}, adjVA_{-1} = 0$

The calculated inputs above are entered into the Live CVOL calculation below:

$$\sigma_N = 100\sqrt{\frac{2}{T_N}\left(\left(\sum_{i=-m}^{-1}\frac{\Delta K_i}{F_N^2}G_N Q\left(P_{K_i}\right)\right) + \frac{1}{F_N^2}G_N * \left(\left(adjVA_{+1}\right)_N + \left(adjVA_{-1}\right)_N\right) + \left(\sum_{i=1}^{n}\frac{\Delta K_i}{F_N^2}G_N Q\left(C_{K_i}\right)\right)\right)}$$

This can be simplified to:

$$\sigma_N = 100 * \sqrt{\frac{2}{T_N}\sum_{i=-m}^{n}\frac{\Delta K_i}{F_N^2}G_N Q\left(O_K\right)}$$

Where:

- m is the index of the lowest struck Put
- n is the index of the highest struck Call
- $Q(P_{K_i})$, $Q(C_{K_i})$ are the option mid-price for the Puts and Calls respectively

4.5. Determining Time

The time T for each strip of options is the amount of time as a fraction of a year (365 days) from the current time until the expiry of those options.

$$T_1 = expiry_1 - t$$

When determining a constant forward-looking implied volatility measure using more than one tenor of options strips, then T will be designated with subscripting such as T_1 and T_2.

Each tenor of options will have its own variance metric, and these two-variance metrics will be time-weighted to a specific time horizon (for example 30 days T_H, where $H = 30\ DTE$). The time weighting applied is defined as follows:

$$\sigma_H = \sqrt{\frac{(T_2 - T_H)(\sigma_1^2) + (T_H - T_1)(\sigma_2^2)}{T_2 - T_1}}$$

Where:

- T_1 is the time to expiry of the front tenor, as expressed in milliseconds
- T_2 is the time to expiry of the back tenor, as expressed in milliseconds
- T_H is the time horizon of the CVOL
- σ_1 is the variance of the front tenor
- σ_2 is the variance of the back tenor
- σ_H is the time-weighted CVOL level.

4.6. Derivative Indicators

Below are the formulae for the CVOL metrics:

- $DownVar_N = 100\sqrt{\frac{2}{T_N}\left(\left(\sum_{i=-m}^{-1} \frac{\Delta K_i}{F_N^2} G_N Q\left(P_{K_i}\right)\right) + \frac{1}{F_N^2} G_N * \left(adjVA_{-1}\right)_N\right)}$

- $UpVar_N = 100\sqrt{\frac{2}{T_N}\left(\frac{1}{F_N^2} G_N * \left(adjVA_{+1}\right)_N + \left(\sum_{i=1}^{n} \frac{\Delta K_i}{F_N^2} G_N Q\left(C_{K_i}\right)\right)\right)}$

- $Skew\ Ratio_N = \frac{UpVar_N}{DownVar_N}$

- $Skew\ Difference_N = UpVar_N - DownVar_N$

- $Convexity_N = \frac{CVOL_N}{ATM_N}$

- $ATM_H = \sqrt{\frac{(T_2 - T_H) * (ATM_1^2) + (T_H - T_1) * (ATM_2^2)}{(T_2 - T_1)}}$

Where:

- T_1 = the time to the shorter dated tenor
- T_2 = the time to the longer dated tenor
- T_H = the time to the target time-horizon
- ATM_1 = the ATM value for tenor pertaining to tenor T_1
- ATM_2 = the ATM value for tenor pertaining to tenor T_2
- ATM_H = the ATM value for time horizon T_H

5. Live Reprint Logic

The following section describes the metrics and thresholds used that can trigger a reprint of a given calculation.

- Data Checks:
  - Future Value Test: If a value for the Future (F_N) cannot be calculated (i.e. a synthetic Future value and the mid of the Future both cannot be calculated), the calculation fails and a reprint is issued.
  - Minimum Data Viability Test: If, after data filtering, there is not at least one strike in each option wing of each tenor, the calculation fails and a reprint is issued.
- Value Checks: The values of the current calculation (t) are compared against the last printed value ($t-1$), which represents the values of the last valid calculation for each of the following metrics:
  - ATM: If $\left|ATM_t - ATM_{t-1}\right| > 0.02 * ATM_{t-1}$, the test is failed and the values of $t-1$ are reprinted.
  - CVOL: $\left|CVOL_t - CVOL_{t-1}\right| > 0.05 * CVOL_{t-1}$, the test is failed and the values of $t-1$ are reprinted.
  - Strike Count ($K\ Count$): If $K\ Count_t < 0.95\ K\ Count_{t-1}$, the test is failed and the values of $t-1$ are reprinted.
  - Skew: If $\left|Skew_t - Skew_{t-1}\right| > 0.1 * Skew_{t-1}$, the test is failed and the values of $t-1$ are reprinted.

If the Live Streaming CVOL calculation has been reprinted for a period of 2 minutes or less, the checks described above are used to compare t against the last calculation that was not a reprinted value.

Establishment of new CVOL Level

If the Live Streaming CVOL calculation at time t is proceeded by a reprinted calculation at $t-1$ and the period of time for which the reprinted value has been printing exceeds 2 minutes, the process below is followed:

- Calculate CVOL and ATM for three consecutive observations (referred to as S_t, S_{t-1}, S_{t-2}).
- Using S_t, S_{t-1}, S_{t-2}, calculate a moving average of CVOL and ATM (referred to as $CVOL_{MA}$, ATM_{MA}).

- If all the following tests pass, reprinting is ended and the metrics pertaining to S_t are printed:
    - ATM: If $\left|ATM_{S_t} - ATM_{MA}\right| > 0.02 * ATM_{MA}$, the test is failed and the values of $t - 1$ are printed.
    - CVOL: $\left|CVOL_{S_t} - CVOL_{MA}\right| > 0.05 * CVOL_{MA}$, the test is failed and the values of $t - 1$ are printed.
    - Strike Count ($K\ Count$): If $K\ Count_{S_t} < 0.8\ K\ Count_{t-1}$, the test is failed and the values of $t - 1$ are printed.
- If any of the above tests fail, the process is repeated at the next calculation snapshot.

6. Market Opening Sequence

The Market Opening Sequence represents the first 5 minutes of the product calculation window. During this period the Live Streaming CVOL calculation is performed but not published to provide the algorithm time to become calibrated to the market data as a trading session begins.

For the beginning of a given trading session, the following logic is followed, noting that no values are published until the Market Opening Sequence has completed:

- At the beginning of a session, the last available End-of-Day CVOL number is used as the initial baseline for all metrics. The strike count by tenor is set to a baseline of 2 strikes by tenor.
- The first calculation in the Market Opening Sequence uses the baseline of the End-of-Day CVOL as the $t - 1$ calculation to compare all metrics against.
- The calculation follows the same process as set out in Calculation Approach and Live Re-Print Logic.
- At the end of the Market Opening Sequence, the most recent valid CVOL value is printed as the first print of the market session.
- If a valid CVOL was unable to be calculated during the Market Opening Sequence, the previous End-of-Day CVOL number will be printed. In this scenario, the calculation engine will continue to apply the approach set out in the Establishment of a new CVOL level above.

7. Tenor Selection Process

The Tenor Selection Groups are used to determine the tenor selection applied to each Live Streaming CVOL calculation. The option contracts used for a given calculation session remains the same throughout the entire calculation session, even if a change in expiry would theoretically cause a shift in the tenor selection. The first action in the Market Opening Sequence, prior to any calculation, is to apply the tenor selection criteria on existing contracts and identify the contracts to be used for the calculation session.

To determine which tenors are used, the available live DTEs are taken and rounded down to an integer value. If after rounding, the DTE is equal to the time horizon the CVOL is trying to measure (i.e. is exactly 30, 60, or 90 DTE), the tenor selection is assessed using the unrounded DTEs of the tenors to ensure two tenors are selected.

Tenor Selection 1

Tenor Selection 1 is not currently used for the Live Streaming CVOL calculation.

Tenor Selection 2

Far contract selection:

- The Monthly expiration > 30.0 DTE and greater than the DTE of the Near contract (if the Near expiry is > 30.0 DTE) and is the closest monthly to 30 DTE.

Near contract selection

- The Monthly expiration closest to 30.0 DTE and < 30.0 DTE and ≥ 10.0 DTE.
- If there is no contract 10.0 DTE ≤ Monthly < 30.0 DTE, then select the closest expiration to 30.0 DTE.

Tenor Selection 3

Tenor Selection 3 is not currently used for the Live Streaming CVOL calculation.

Tenor Selection 4

Far contract selection:

- The Monthly contract expiration > 30.0 DTE and closest to 30.0 DTE.

Near contract selection:

- The Monthly contract expiration 14.0 ≤ DTE < 30.0 and closest to 30.0 DTE.
- If the shorted dated monthly contract(s) expiration is/are DTE < 14.0 OR DTE > 30.0, then Friday Weekly 14.0 ≤ DTE ≤ 21.0 and closest to 30.0 DTE is selected.

Tenor Selection 5

Far contract selection

- The Monthly, Weekly or End-of-Month (EOM) expiration > 30.0 DTE and closest to 30.0 DTE.

Near contract selection

- The Monthly, Weekly or EOM expiration < 30.0 DTE and closest to 30.0 DTE.

Tenor Selection 6 (60 DTE)

In some instruments, the market dynamics cause the practical utility of the option contract to cease approximately one month before expiry. In these markets, a 60.0 day horizon is used as it is effectively equivalent to the 30.0 day horizons employed in the other CVOL indices.

Far contract selection:

- The Monthly expiration > 60.0 DTE and greater than the DTE of the Near contract (if the Near expiry is > 60.0 DTE) and is the closest monthly to 60.0 DTE.

Near contract selection

- The Monthly expiration closest to 60.0 DTE and < 60.0 DTE and ≥ 20.0 DTE.
- If there is no contract 20.0 DTE ≤ Monthly < 60.0 DTE, then select the closest expiration to 60.0 DTE.

Tenor Selection 7 (90 DTE)

In some instruments, the underlying future of the option contract has a quarterly expiration. In these markets, a 90.0 day horizon is used as it is effectively equivalent to the 30.0 day horizons employed in the other CVOL indices.

Far contract selection:

- The Monthly expiration > 90.0 DTE and greater than the DTE of the Near contract (if the Near expiry is > 90.0 DTE) and is the closest monthly to 90.0 DTE.

Near contract selection:

- The Monthly expiration closest to 90.0 DTE and < 90.0 DTE and ≥ 50.0 DTE.
- If there is no contract 50.0 DTE ≤ Monthly < 90.0 DTE, then select the closest expiration to 90.0 DTE.

8. Short Term Interest Rate (STIR) Methodology

Due to the nature of the STIR Futures market, the SOFR based Live Streaming CVOL indices require an alternative calculation methodology. The calculation of the single tenor volatility value is derived from the Live Streaming CVOL index calculation approach and is shown below:

$$Single\ Tenor\ Index = \sigma_N = 100 * \sqrt{\frac{2}{T}\sum_{i=m}^{n} \Delta K_i G_N Q\left(O_{K_i}\right)}$$

9. Yield-Volatility Methodology

In order to render the price-based volatility as a basis point volatility the DV01 is used. The DV01 is the change of a bond price for a 1 basis change of the rate associated with that bond. To convert a futures price volatility into a BP volatility, the transformation happens at the variance level.

$$\sigma_{bp}^{2} = \sigma^{2} * \frac{F^{2}}{DV01^{2}}$$

From the prior calculation

$$\sigma = \sqrt{\frac{\left(T_2 - T_H\right)*\left(\sigma_1^2\right)+\left(T_H - T_1\right)*\left(\sigma_2^2\right)}{\left(T_2 - T_1\right)}}$$

Substituting the DV01 formula

$$\sigma_{bp} = \sqrt{\frac{\left(T_2 - T_H\right)*\left(\sigma_1^2\right)*\left(\frac{F_1^2}{DV01_1^2}\right)+\left(T_H - T_1\right)*\left(\sigma_2^2\right)*\left(\frac{F_2^2}{DV01_2^2}\right)}{\left(T_2 - T_1\right)}}$$

10. Broad Based Indices

Due to the composition of the Broad-Based Indices with certain products having different market hours, the index calculation uses the last printed CVOL observation for each component. The weightings of the components of the Broad-Based Indices are determined by the Dollar Vega Data from the most recent End-of-Day data and persist for the entire day.

The following table outlines the current Broad Based Indices, with the market calculation times and the component times provided in the Product Calculation Windows section:

Symbol	Name	Components
AVL	Ag Products Volatility Index	OZC, OZW, OZS, OZM, OZL, LE, HE, DC, GF
ENVL	Energy Volatility Index	LO, LN, OB, OH
FXVL	FX Volatility Index	EUU, GBU, JPU, AUU, CAU
TPVL	Treasury Curve Volatility Index - Price	TU, FV, TY, US (price version)
TVL	Treasury Curve Volatility Index - Yield	TU, FV, TY, US (yield version)
CMVL	Commodities Volatility Index	LO, LN, OH, OB, OZC, OZW, OZS, HXE, OG, SO, LE, HE, DC
MVL	Metals Volatility Index	OG, SO, HXE, PO

The calculation of the indices described above is the sum of Implied Volatility Calculations weighted by the Dollar Vega Open Interest ($\$VOI$). The dollar Vega Open Interest can be defined as follows:

$$\$VOI_T = M \sum_{t=0}^{i} \sum_{k=0}^{j} v_{t,k}(CVOL) * OI_{t,k}$$

We then use five days of $\$VOI$ to arrive at a five-day moving average as defined below:

$$MA_{T=0} = \frac{\sum_{T=-1}^{-5} \$VOI_T}{5}$$

Where:

- t tenor of a given option.
- T is the day of a given $\$VOI$, where T_{-5} is five settlement days prior to the current calculation day.
- k is the strike of a given option from the EoD settlement data
- $v_{t,k}(CVOL)$ is the Vega of option position t, k from the EoD settlement data with CVOL being used for the σ in the d_1 and d_2 terms of vega.
- $OI_{t,k}$ is the Open Interest of option position t, k (both Calls and Puts) from the EoD settlement data
- M is the contract multiplier/Contract Value Factor (CVF) associated with the product for the option position

Using the five-day moving averages, we formulate the weighting for each product using the following definition:

$$W_n = \frac{MA_n}{\sum_{n=1}^{q} MA_n}$$

Where:

- q is the number of products being combined into the index
- MA_n is the 5-day moving average of the $\$VOI$

With the weightings calculated, we take the final step and calculate the index by combining the weightings and Volatility values for each respective product in the following manner:

$$\sigma_{index} = \sum_{n=1}^{q} \sigma_n * W_n$$

11. Publication

The Live Streaming CVOL Indices are calculated and published every 15 seconds during the times defined in Product Calculation Windows. The Live Streaming CVOL Indices follow the CME Globex Holiday Calendar.

If an error is reported in the input data or in the calculation, the Index is not re-calculated.

In the event of disruptions to the standard Live Streaming CVOL Indices' publication process, CBA, where deemed necessary, will release publication alerts with respect to issues impacting the availability of the index. Publication alerts will be made available via the CME Globex system utilising the GCC System Alerts.

In addition, CBA may, at its discretion, release information notices with respect to issues impacting the availability of the Live Streaming CVOL Indices, via the CBA Notice Page.

12. Use of Expert Judgement

Expert judgement is not used in the ordinary day to day determination of the Live Streaming CVOL Indices.The benchmark calculation methodology is rules-based and designed to consistently produce robust and reliable values which do not rely on expert judgement. However, CBA, in its capacity as Administrator of the Live Streaming CVOL Indices, may exercise such expert judgement in unforeseen and extraordinary circumstances when deemed necessary to maintain the integrity, accuracy and reliability of the benchmark. These circumstances can include, but are not limited to: index restatements, periods of market stress or disruptions, or periods where data sources may be absent or become unreliable. Where such circumstances arise, a notice will be published on the CBA Notice Page.

The elements of the calculation of the benchmark in relation to which expert judgement may be exercised, can include, but are not restricted to, the following: (i) excluding certain input data from the calculation; (ii) adjusting/varying any component of the benchmark calculation; or (iii) delaying/estimating the value of input data.

Any exercise of expert judgement by the Administrator can only be carried out by suitably experienced, qualified staff members who have the authority to exercise such judgement as part of their function. The exercise of expert judgement by the Administrator will be reported to the BMR Joint Oversight Committee and the CME Group Benchmark Administration (CBA) Product Advisory Committee (together the Oversight Committees) to ensure that it has been applied consistently and in accordance with the applicable benchmark administration standards and benchmark methodology. The Administrator will retain all internal records detailing the use of expert judgement and the rationale for its use to allow for any ex-post review.

13. Governance

13.1. Oversight Committees

The Administrator has implemented a tiered oversight committee structure, which in combination, performs the overall duties of the Oversight Function, as defined under Article 5 UK and EU BMR (collectively, the "BMR"). The purpose of the Oversight Function is to review the accuracy, representativeness, reliability and integrity of benchmarks provided by CBA by providing independent oversight and challenge to the Administrator.

Please see a description of these Oversight Committees below:

• The BMR Joint Oversight Committee ("JOC") is responsible for the overall direction and coordination of the Oversight Function and for interaction with the management body of CBA. The JOC is supported by and is an escalation point for the CME Group Benchmark Administration (CBA) Product Advisory Committee. Please refer to the JOC Terms of Reference for full details of the responsibilities of the JOC. They are available on the CBA Benchmark Governance website.

• The CME Group Benchmark Administration (CBA) Product Advisory Committee ("PAC") presides over major methodology developments and changes relating to specific index families as well as cessation and/or consultation decisions. The PAC provides technical oversight of the operation of the benchmarks as well as the underlying market and how changes could impact the continued representativeness and integrity of the benchmarks. The PAC provides its views and recommendations to both the JOC and the CBA Management. Please see the Terms of Reference for the Product Advisory Committees for further information. They are available on the CBA Benchmark Governance website.

13.2. Review of the Calculation Guide

The Calculation Guide is reviewed and approved annually by the Administrator and is reviewed annually by the Oversight Committees.

The Oversight Committees review material changes to the Calculation Guide including, but not limited to, the structure of the Indices, input data used and all aspects of the calculation methodology.

The Oversight Committees may request the Administrator to consult on any changes to the Calculation Guide with stakeholders and the wider market.

13.3. Consultation Process

Where material changes to Live Streaming CVOL Indices become necessary, the Administrator will engage stakeholders and users by way of a public consultation.

Changes are deemed material on the basis of an assessment conducted by the Administrator and submitted to the Oversight Committees for advice and feedback.

The Administrator will publish notice of the consultation on its website, inviting feedback from stakeholders and the wider market. Where practicable, notice of a consultation will be posted at least 1 (one) month prior to the deadline for responses. The notice will include the details of the proposed material change, the timeline and the rationale for the change.

Findings of the consultation process and proposed changes to the Calculation Guide, recommended as a result of the consultation, will be presented by the Administrator to the Oversight Committees for their consideration.

Feedback to a consultation is considered confidential.The Administrator will publish an anonymized summary with its conclusions, as soon as is practical, but before implementation of any changes.

13.4. Cessation

The Administrator constantly monitors the representativeness of the Live Streaming CVOL Indices. If the Live Streaming CVOL Indices are deemed to be unrepresentative of the underlying economic reality due to paucity of input data or systemic changes in the related markets, the Administrator will engage the Oversight Committees at the earliest opportunity. These cessation arrangements are designed to mitigate cessation and transition risks.

The Oversight Committees are responsible for reviewing and approving procedures for cessation of the Live Streaming CVOL Indices.

The Oversight Committees may direct the Administrator to consult with stakeholders as described in the Consultation Process section.

As a last resort, if no alternative arrangements are feasible, the Oversight Committees may advise the Administrator to discontinue the Live Streaming CVOL Indices, providing stakeholders reasonable notice and assistance to explore alternative reference instruments.

The Administrator will endeavour to identify alternative benchmarks; however, this might not always be possible due to regulations, market conditions or a lack of suitable alternatives.

Users of the Live Streaming CVOL Indices are recommended to ensure that they have adequate fallback policies and procedures in the event of the Live Streaming CVOL Indices becoming unrepresentative of its economic interest.

13.5. Record Retention

The Administrator has in place policies for the retention of any relevant evidence and documentation related to the determination and dissemination of the Benchmark, either in paper or in electronic format, for at least the mandatory term of 5 (five) years.

13.6. Auditing

An audit process will be undertaken regularly, to ensure adherence to the stated Guide, the IOSCO principles and regulatory requirements.

13.7. Data Licensing and Distribution

The Benchmark is made available subject to execution of an Information License Agreement (ILA) with CME Inc. together with the appropriate Schedules. Market participants that intend to subscribe to the Benchmark should contact the Administrator at the following email address: datasales@cmegroup.com.

13.8. Complaints Procedure

The CBA Complaints Procedures set out details on the management of customer complaints to ensure that they are handled fairly and effectively, in a prompt and transparent manner and in accordance with applicable regulatory requirements.

Complaints will be dealt with by a senior member of staff not directly involved with the benchmark calculation and dissemination. Information related to complaints will be stored in a restricted access area and kept for a period of at least 5 (five) years following the date when the complaint was first lodged. Complaints can be submitted at internationalcompliance@cmegroup.com