IEC Standardization and Vanadium Market Update

Terry Perles, TTP Squared

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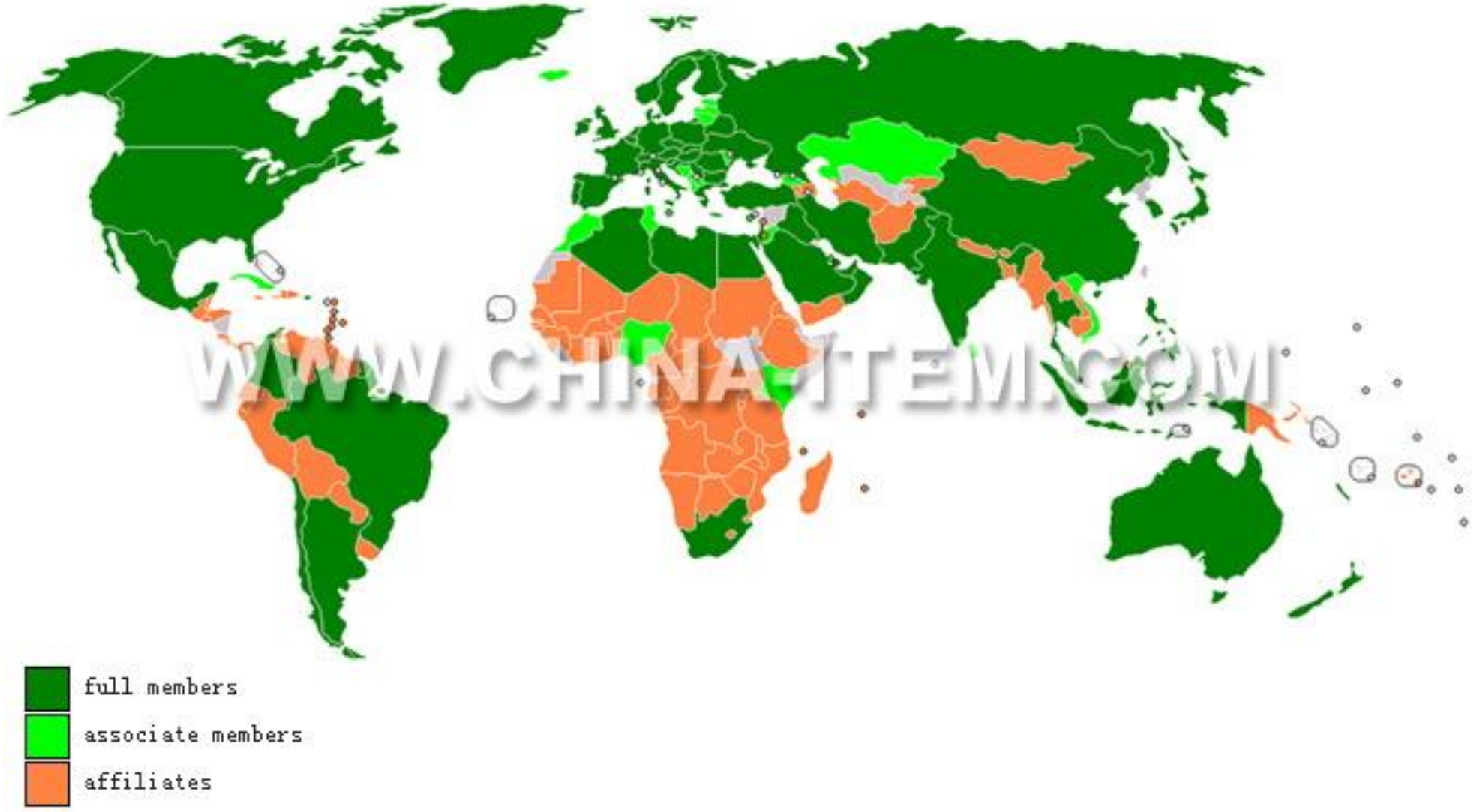
Vanadium Flow battery Electrolyte Specification standardization

Electrolyte Specification standardization

- International Electrochemical Commission - The world's leading organization for the preparation and publication of international standards for all electrical, electronic and related technologies

IEC Members, Associate Member and Affiliate Countries



International Electrochemical Commission

- Works through national standard setting organizations globally
- Technical Committee 21 (TC21) – Secondary Cells and Batteries
  - Joint Working group 7 (JWG7) – Flow Battery Systems for Stationary Applications

Participants in IEC TC21 JWG7

- 74 members
- Countries represented: USA, Germany, Singapore, Netherlands, Spain, China, South Korea, Austria, India, United Kingdom, Nigeria, Japan, South Africa, Denmark, Kenya, Hungary

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Participants in the 9th meeting of the IEC TC21 JWG7 Tokyo, Japan March 17-19, 2025

Function	Last Name	First Name	NC	Email	Participated		
					17-Mar. Mon	18-Mar. Tue	19
Convener	Shiga	Nobuo	JP	shiga-nobuo@sei.co.jp	×	×	
Secretary	Yamada	Yuichi	JP	yamada-yuichi@sei.co.jp	×	×	
PL	Shibata	Toshikazu	JP	tshibata@sei.co.jp	×	×	
Acting-PL	Roznyatovskaya	Nataliya	DE	nataliya.roznyatovskaya@ict.fraunhofer.de	V	V	
Member	Chen	Yanbo	CN	chenyb@bnm-bolong.com	×	×	
Member	Li	Xianfeng	CN	lixianfeng@dicp.ac.cn	V	V	
Member	Liu	Zi	CN	liu_zi@ctg.com.cn	V	V	
Member	Song	Mingming	CN	songmm@bnm-bolong.com	×	×	
Member	Wang	Xiaoli	CN	xiaoli.wang@rongkepower.com	V	-	
Member	Zheng	Qiong	CN	zhengqiong@dicp.ac.cn	V	V	
Member	Beyer	Thomas	DE	thomas.beyer@gfe.com	V	V	
Member	Seiler	Yannick	DE	yannick.seiler@ict.fraunhofer.de	×	×	
Member	Kazuo	Shibata	JP	kazuo_shibata@jema-net.or.jp	×	V	
Member	Sato	Yukari	JP	yukari-sato@aist.go.jp	×	V	
Member	Tabuchi	Naoya	JP	naoya_tabuchi@jema-net.or.jp	×	×	
Member	Tatsumi	Ryota	JP	tatsumi-ryouta@sei.co.jp	×	×	
Member	Huh	Jeehyang	KR	jeehyang.huh@h2aec.com	×	×	
Member	Kim	Sungkkuk	KR	skkim82@keri.re.kr	V	-	
Member	Kwon	Kyoungjun	KR	kkj3904@keri.re.kr	×	×	
Member	Berland	Brian	US	brian.berland@stryten.com	×	×	
Member	Perles	Terry	US	terry@ttpsquared.com	×	×	
Guest	Li	Yifeng	AU	Yifeng.li@vsun.com.au	V	V	
Guest	Osawa	Issei	JP	iosawa@rs-tec.jp	V	-	
Guest	Kogami	Yasunori	JP	kogami@rs-tec.jp	×	×	
Guest	Tanaka	Toshiro	JP	ttanaka@rs-tec.jp	×	×	

Why Standardization of Vanadium Flow Battery Specification is important

- Impurities can impact performance of the Vanadium Flow Battery system
- A global standard for electrolyte chemistry will give the electrolyte producers a common target objective and help to develop a global supply chain that can efficiently meet the need of the Vanadium Flow Battery producers.
- Common standard can create a global commodity that can be traded, drawing much needed investment into the Vanadium Flow battery space

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US VANADIUM

USV Review of 17 VRFB Electrolyte Specifications Provided by Battery Suppliers vs USV Specifications

		Low	Average	Mode	High	No Specification*	USV High Purity	USV Ultra High Purity
Catalyze hydrogen production	Cu	<0.03	<2	<1	5	6%	<0.5	<0.1
	Mo	<1	<21	<20	50	18%	<20	<20
	Pd	<0.004	<0.7	<1	1	47%	<0.004	<0.004
Precipitate in anolyte when charging	Sb	<0.1	<0.7	<1	1.3	59%	<0.5	<0.1
	Ag	<0.004	<0.7	<1	1	82%	<0.05	<0.004
	As	<0.03	<2	<1	10	29%	<0.1	<0.1
	Ba	<0.2	<0.6	-	1	88%	-	-
	Ca	<1	<25	<30	70	12%	<30	<30
	Se	<0.02	<0.5	-	1	88%	-	-
	Sr	<0.02	<0.5	-	1	88%	-	-
	Bi	<0.2	<2	<1	5	76%	<0.2	<0.2
May precipitate in anolyte near full charge	Sn	<0.5	<1.1	<1	2	65%	<0.5	<0.5
	Co	<0.1	<11	<1	40	41%	<0.1	<0.1
	Ni	<0.6	<28	<5	270	6%	<5	<5
Potentially precipitate when fully charged in the anolyte or form soluble sulfate	Si	<5	<10	<10	20	24%	<13	<13
Anion that stays dissolved at all times	Cl	<1	<108	<1	400	41%	-	-
Fully soluble cations that remain dissolved at all times	Cr	<1	<30	<5	290	29%	<15	<15
	Fe	<3	<87	<50	450	6%	<60	<50
	Mg	<1	<136	<30	1700	12%	<20	<20
	Na	<2	<173	<50	1700	18%	<50	<50
	Zn	<0.3	<251	<1	2000	53%	<3	<1
	Al	<1	<72.2	<50	650	12%	<50	<50
	Cd	<10	<10	-	10	94%	-	-
	K	<1	<185	<50	1900	18%	<50	<50
	Li	<0.1	<112	<5	500	71%	-	-
	Mn	<0.2	<149	<5	2000	18%	<5	<5
	Pb	<1	<4	<1	10	82%	-	-
Filtered out during production	Ir	<0.004	<0.007	-	0.01	88%	<0.004	<0.004
	Os	<0.01	<0.5	-	1	88%	-	-
	Pt	<0.004	<1.1	<1	4	59%	<0.2	<0.004
	Ge	<1	<1	-	1	94%	-	-
	B	<0.07	<0.07	-	0.07	94%	-	-
	Re	<0.01	<0.01	-	0.01	94%	-	-
	Ru	<0.004	<0.3	-	1	82%	<0.004	<0.004
	Rh	<0.004	<0.3	-	1	82%	<0.004	<0.004
	Ti	<0.4	<2	<1	5	65%	-	-
	W	<0.03	<0.5	-	1	88%	-	-
Could be introduced with some sulfuric acid sources	Tl	<1	<1	<1	1	82%	-	-

values represented in mg/L.

** States the percentage of specifications that did not include a limit for the element.*

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Draft of IEC TC21 JWG7 Electrolyte Standard Specification

March 19, 2025

Table 1: Maximum inorganicimpurities for sulphuric acid based vanadium flow battery electrolytes

Impurity number	Impurity name	Concentration Grade A [mg/L]	Concentration Grade B [mg/L]	Observation of the secretariat
1	Aluminium (Al)	50	100	required
3	Arsenic (As)	0.2	0.5	required
8	Calcium (Ca)	30	50	required
12	Cobalt (Co)	5	20	recommended
13	Chromium (Cr)	20	20	recommended
14	Copper (Cu)	0.5	1	required
15	Iron (Fe)	100	200	required
17	Iridium (Ir)	0.01	0.01	required
18	Potassium (K)	100	200	required
20	Magnesium (Mg)	30	50	required
21	Manganese (Mn)	5	30	required
22	Molybdenum (Mo)	20	30	required
23	Sodium (Na)	50	80	required
24	Nickel (Ni)	10	60	recommended
27	Lead (Pb)	5	5	required
28	Palladium (Pd)	0.01	0.01	required

	Impurity name	**Concentration Grade A** [mg/L]	**Concentration Grade B** [mg/L]	Observation of the secretariat
29	Platinum (Pt)	0.01	0.01	required
30	Rhenium (Re)	0.01	0.01	required
31	Ruthenium (Ru)	0.01	0.01	required
32	Antimony (Sb)	0.2	1	required
34	Silicon (Si)	10	10	required
35	Tin (Sn)	0.5	1	recommended
38	Titanium (Ti)	10	20	required
42	Zinc (Zn)	5	10	required

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Status of Vanadium Flow battery Electrolyte Standardization Process

- Last meeting Tokyo April 2025
- Draft chemical specification for electrolyte has been developed based on input from TC21 JWG7 members

Next Steps

- Next Meeting June 23, 2025 in Vienna preceding the International Flow Battery Forum (IFBF)
- The concept of the establishment of specifications around groups of elements rather than each specific elemental impurity will be considered in some cases
- Analyrical methods and capabilities need to be addressed
- It is envisioned that the standard specification can be issued in 2026.

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Vanadium Market Update

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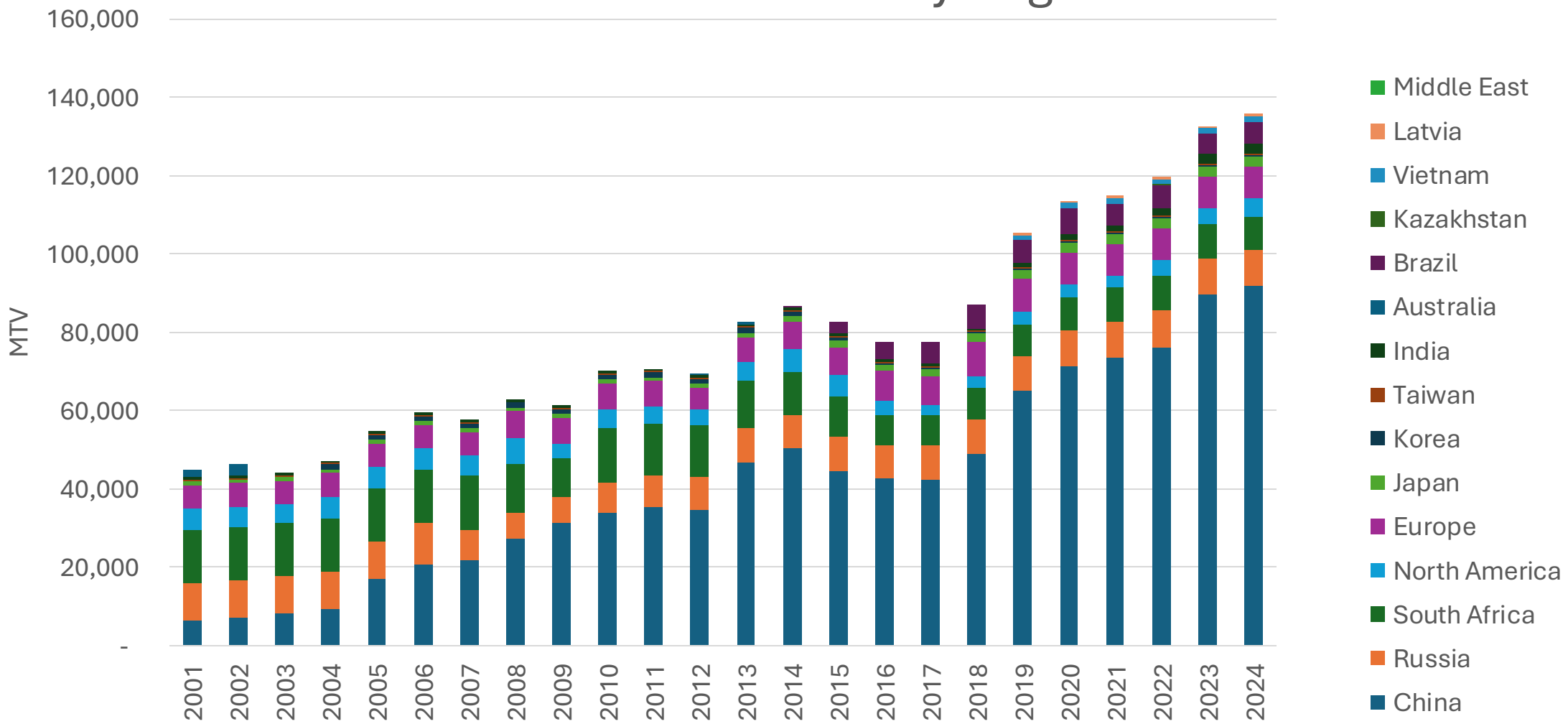
Vanadium Production by Region



Source: VANITEC, TTP Squared, LLC

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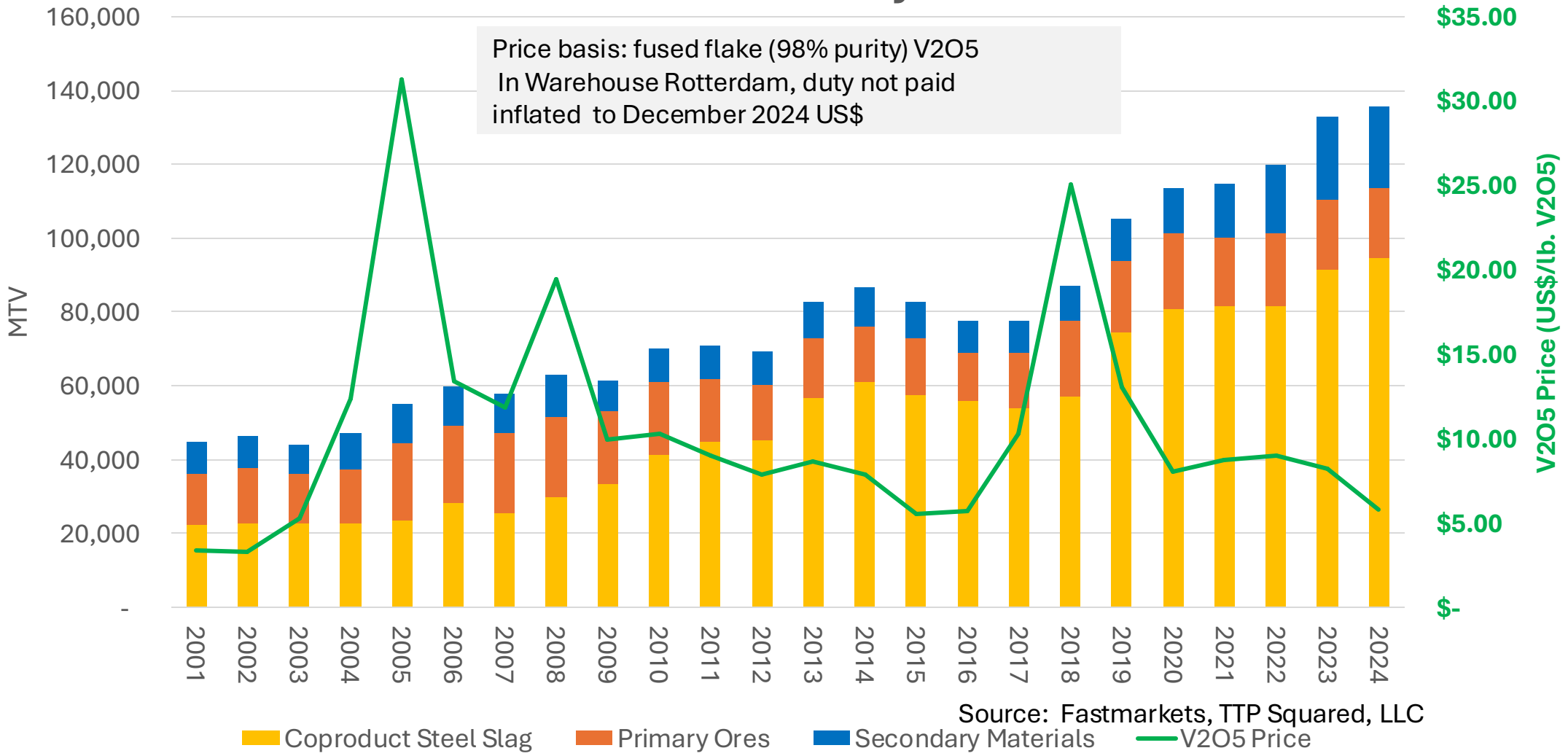
Vanadium Production by Raw Material



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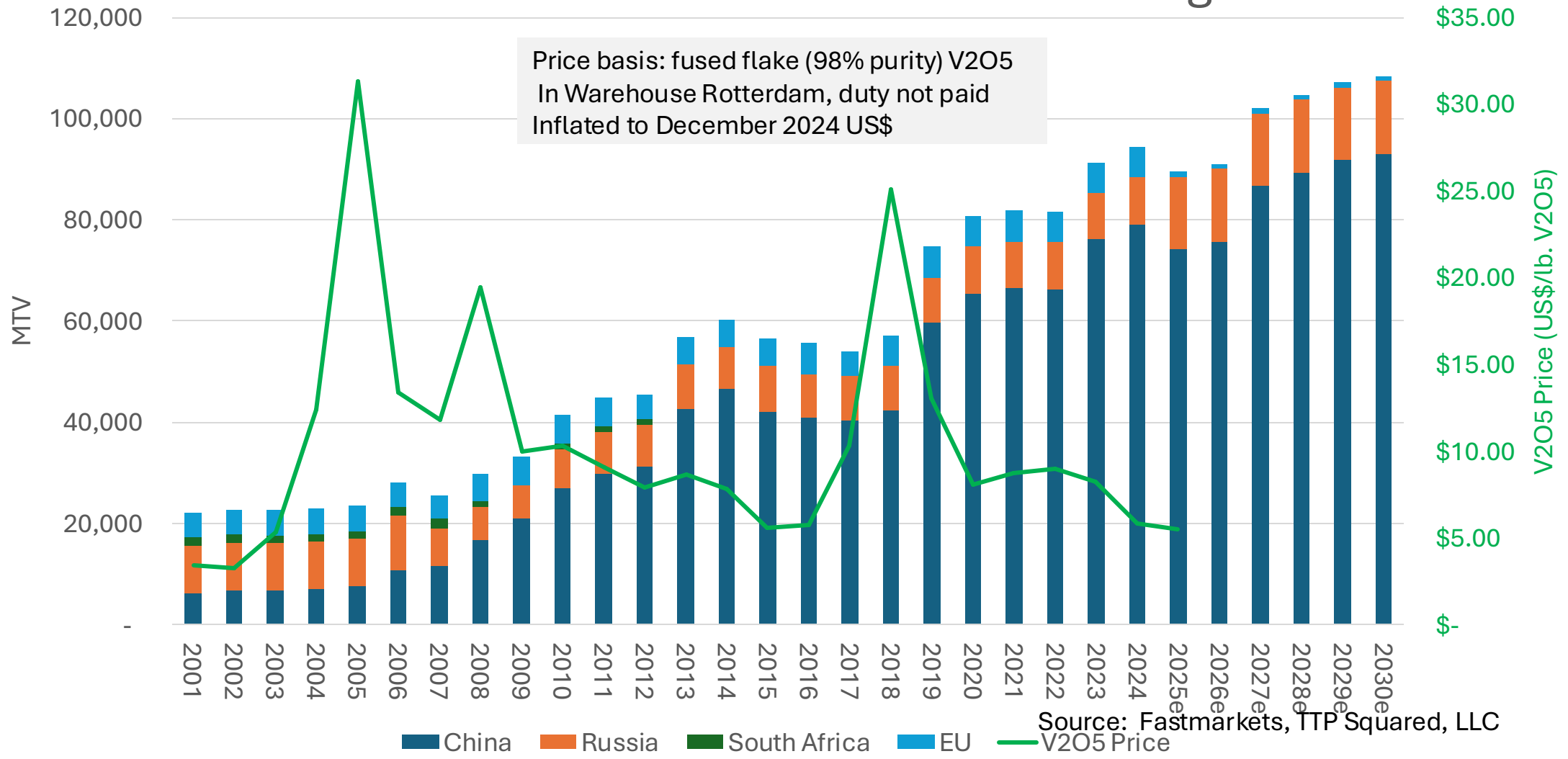
Vanadium Production from Steel Slag



Source: Fastmarkets, TTP Squared, LLC

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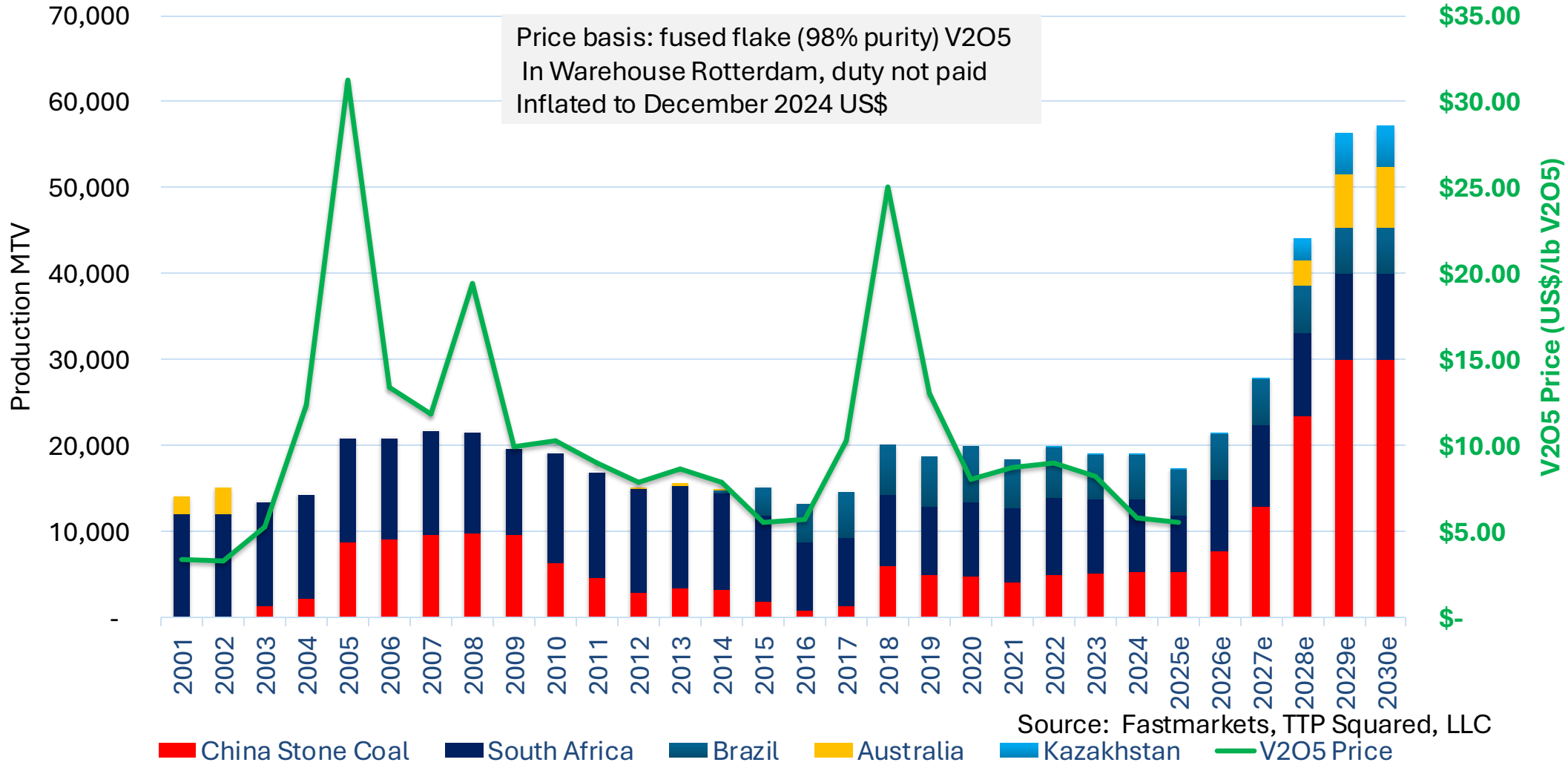
Vanadium Production From Primary Ore



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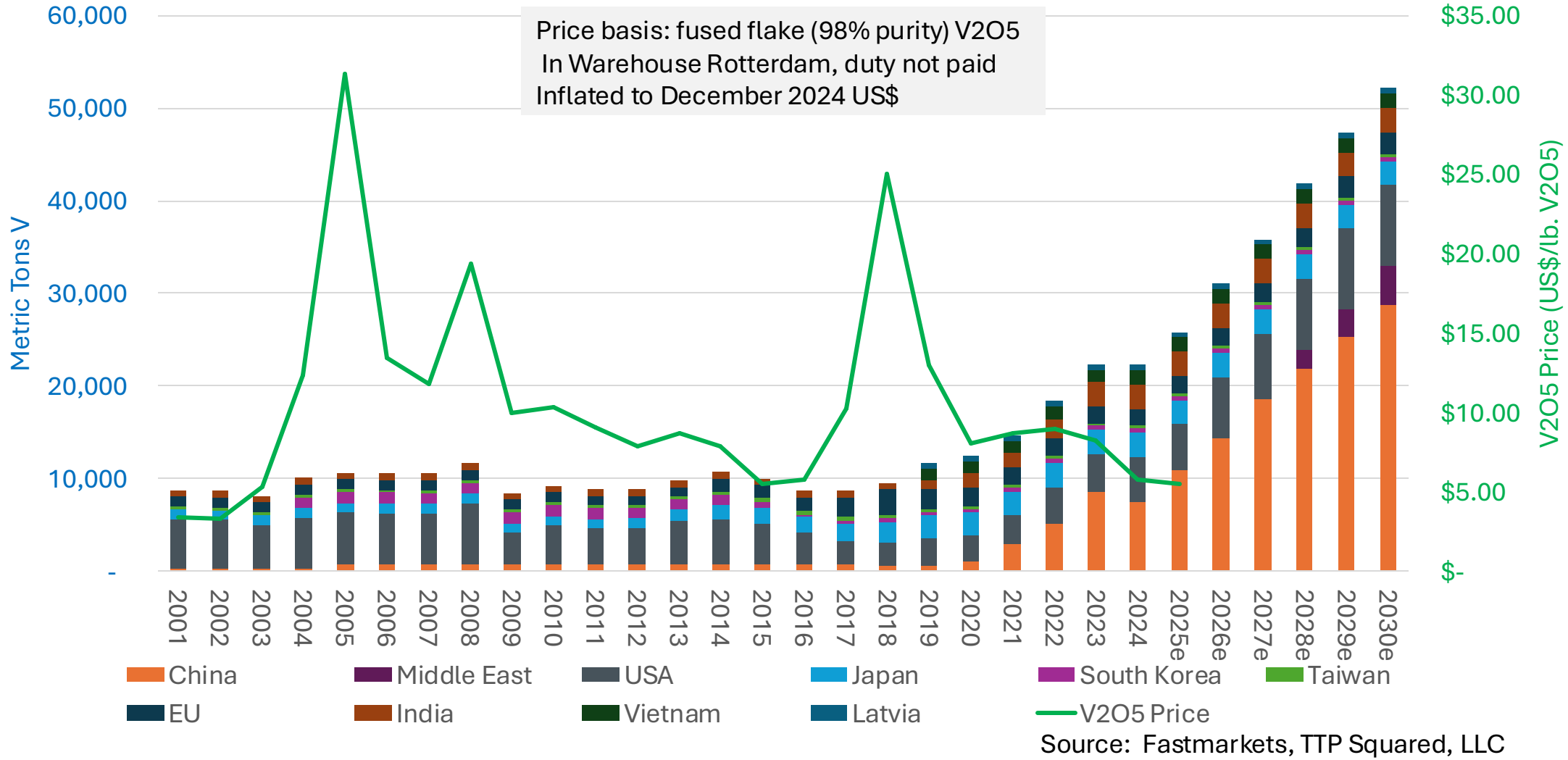
Secondary Vanadium Production



Source: Fastmarkets, TTP Squared, LLC

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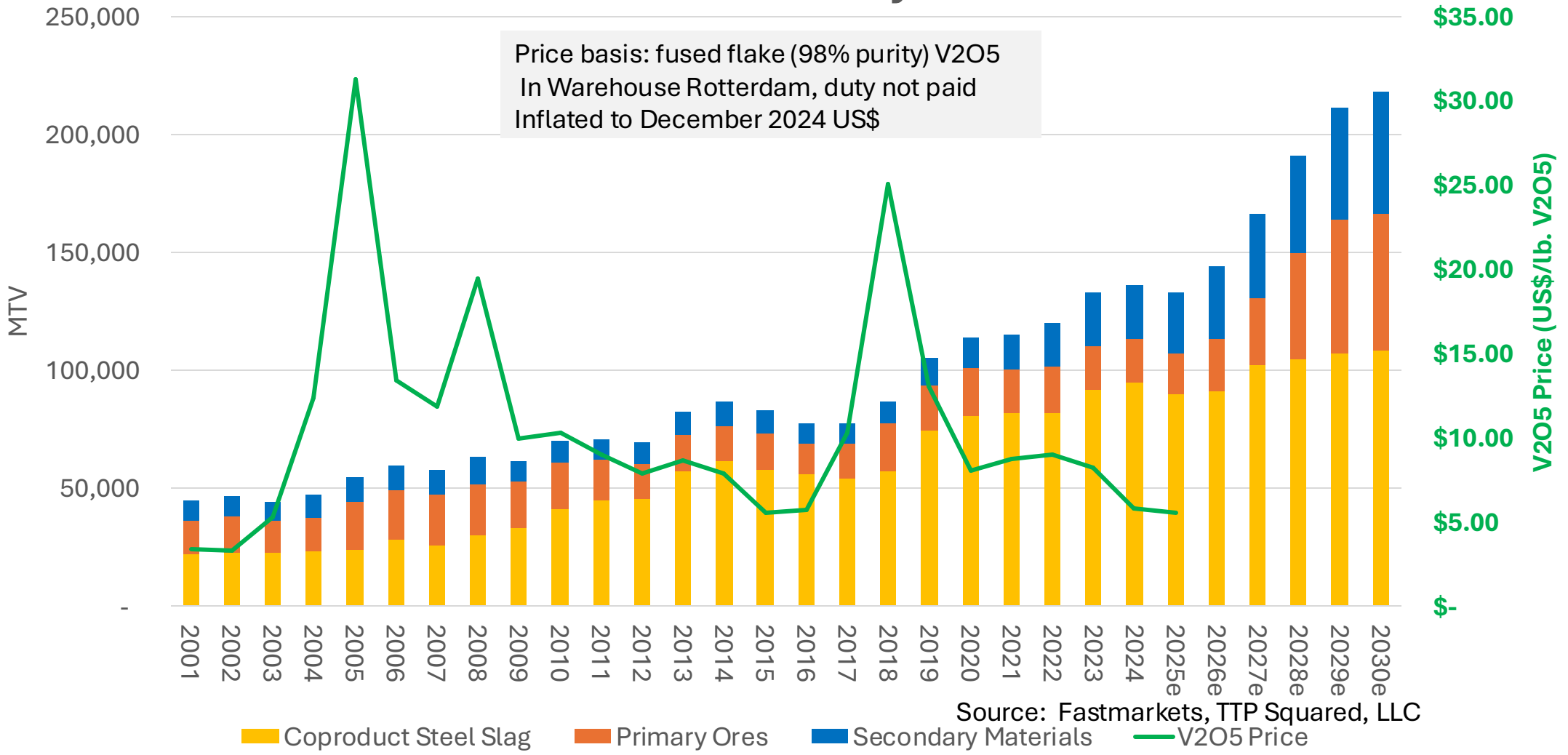
Vanadium Production by Raw Material



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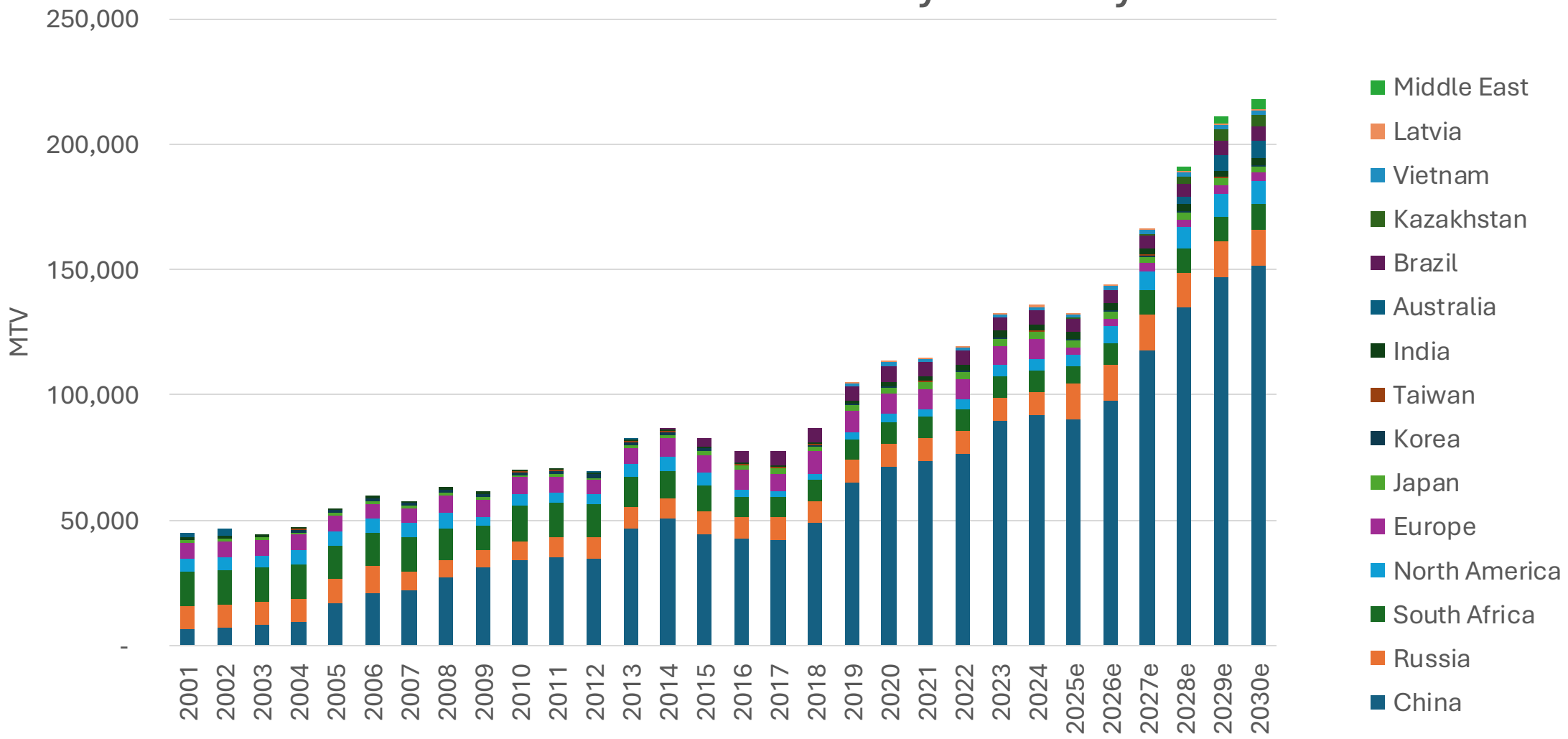
Vanadium Production by Country



Source: VANITEC, TTP Squared, LLC

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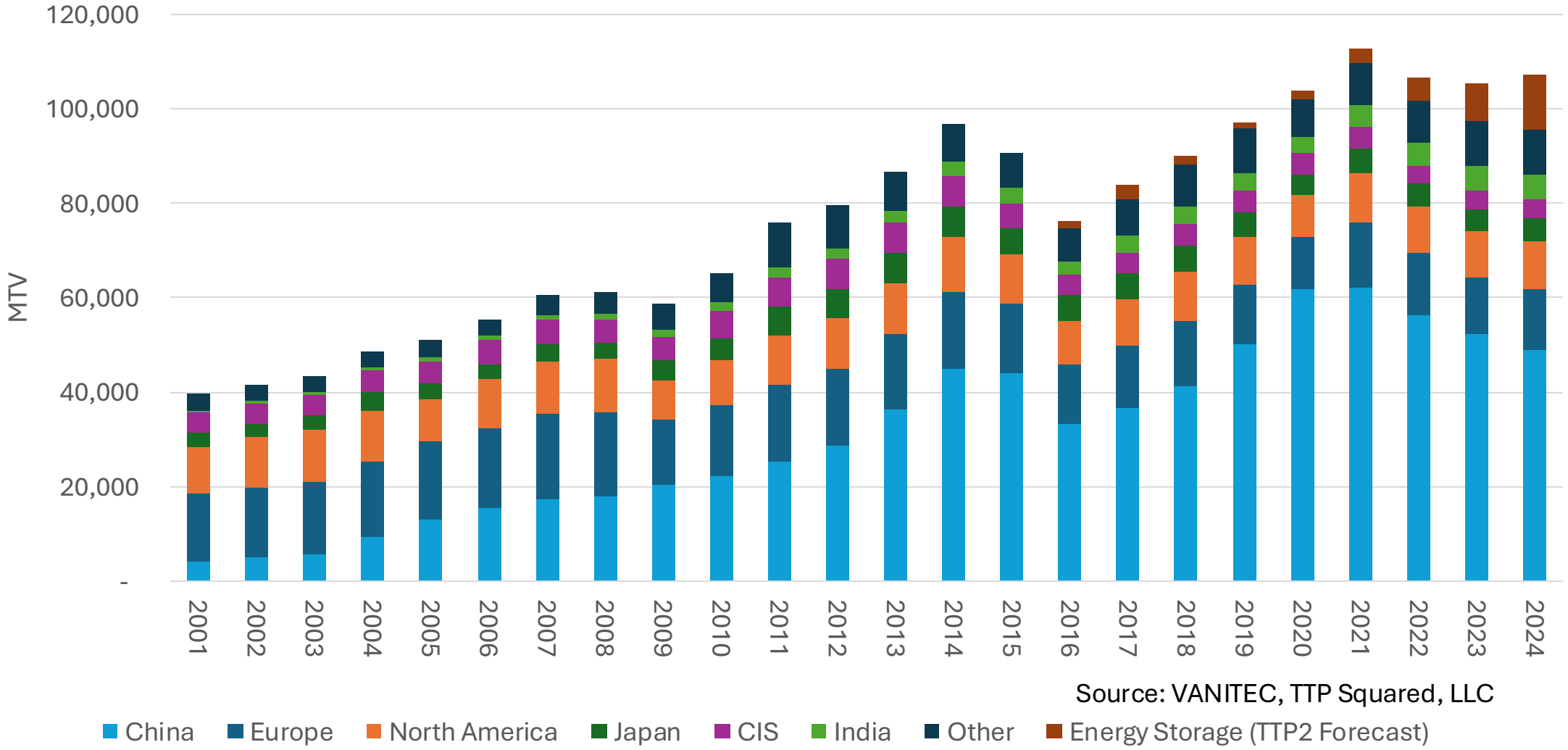
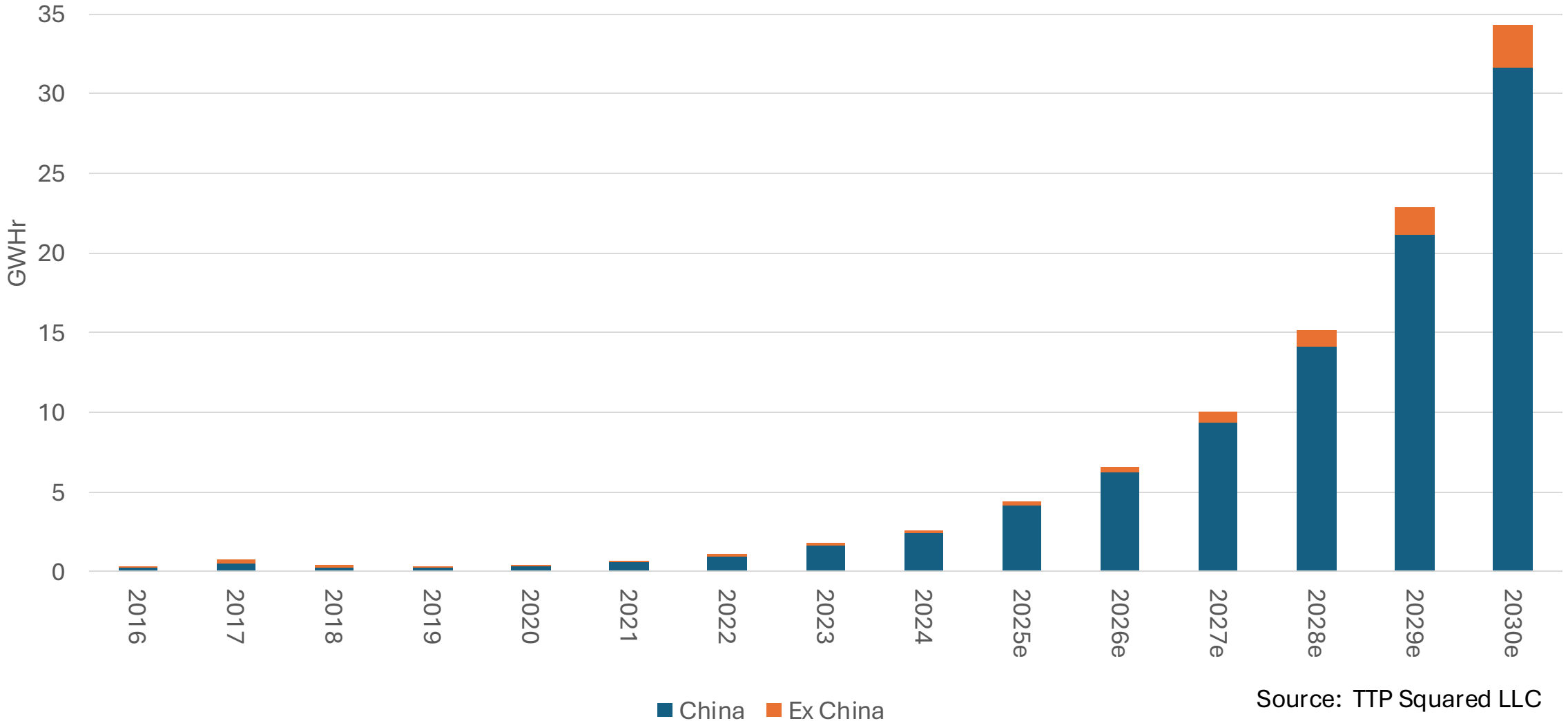
Vanadium Consumption

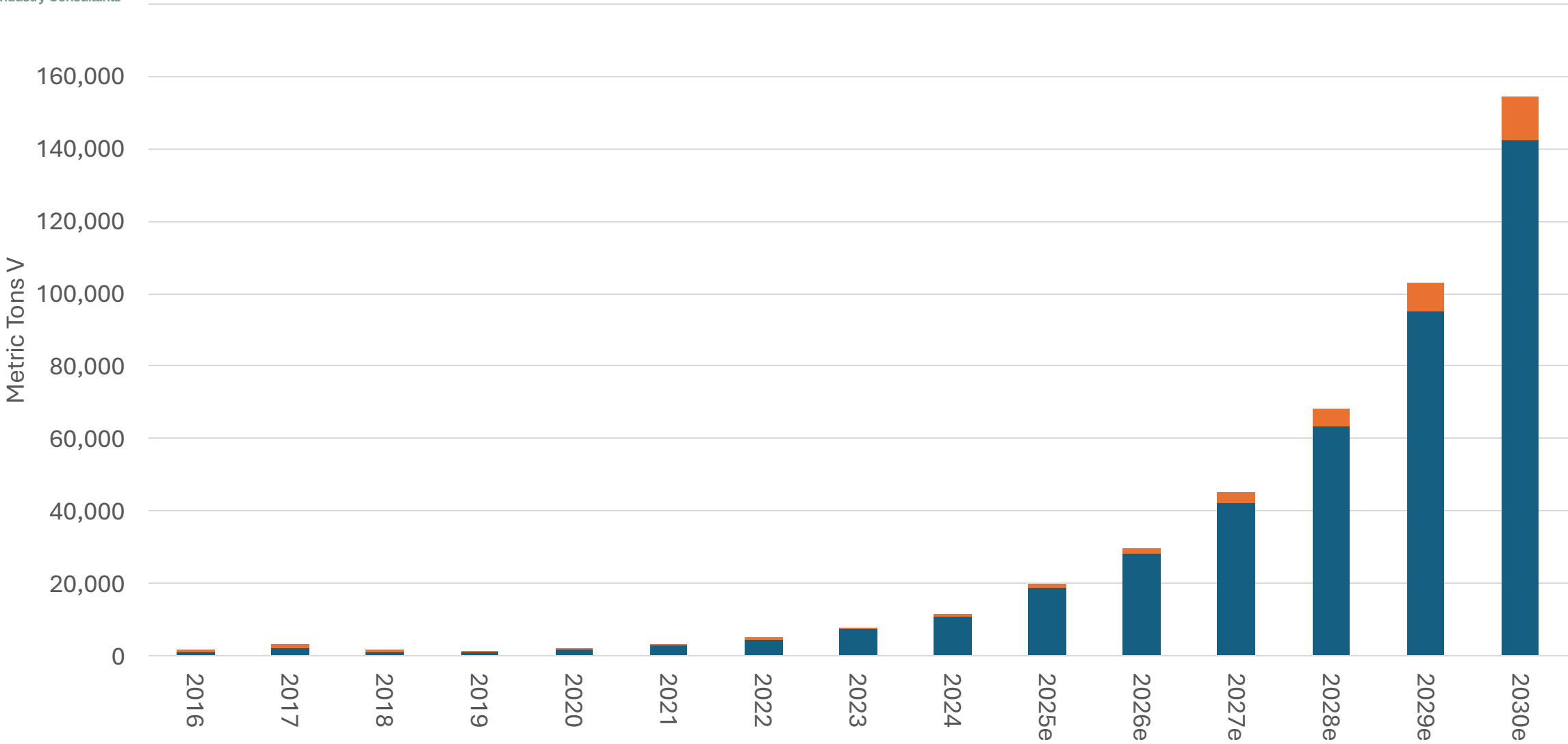


Vanadium Flow Battery Installations



Source: TTP Squared LLC

Vanadium Flow Battery Demand for Vanadium



Source: TTP Squared LLC

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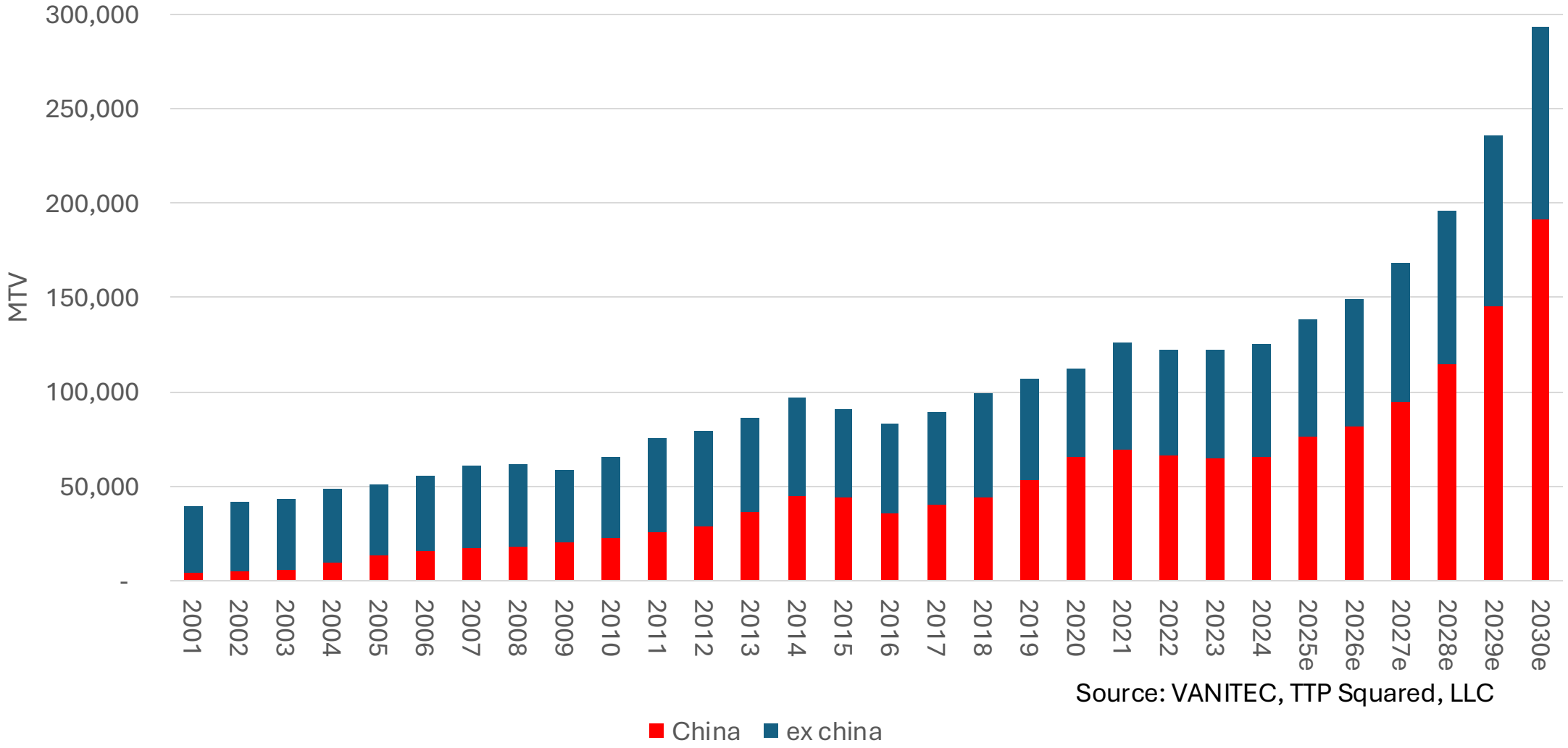
Vanadium Consumption



Source: VANITEC, TTP Squared, LLC

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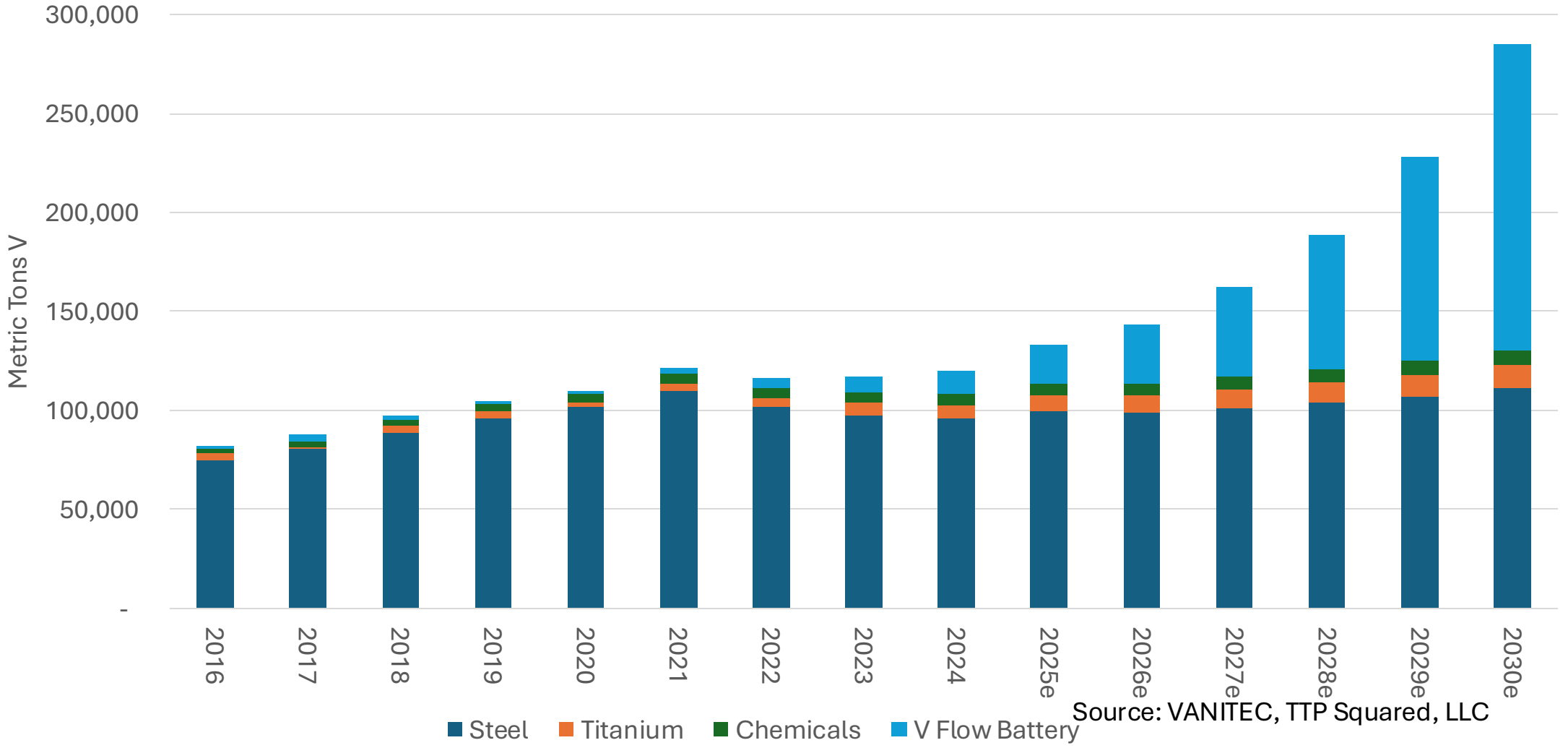
Vanadium Consumption by Application



Source: VANITEC, TTP Squared, LLC

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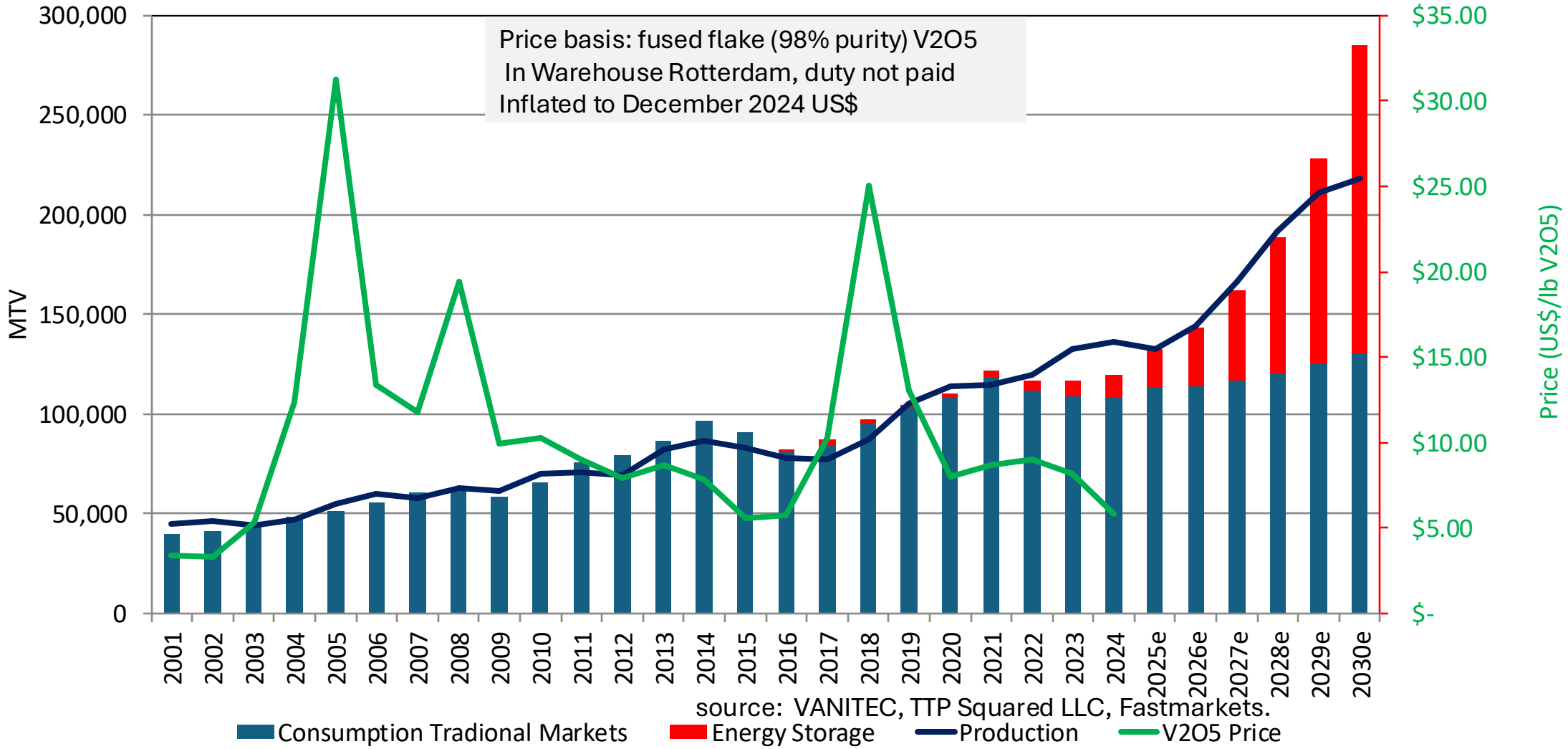
V Consumption and Production



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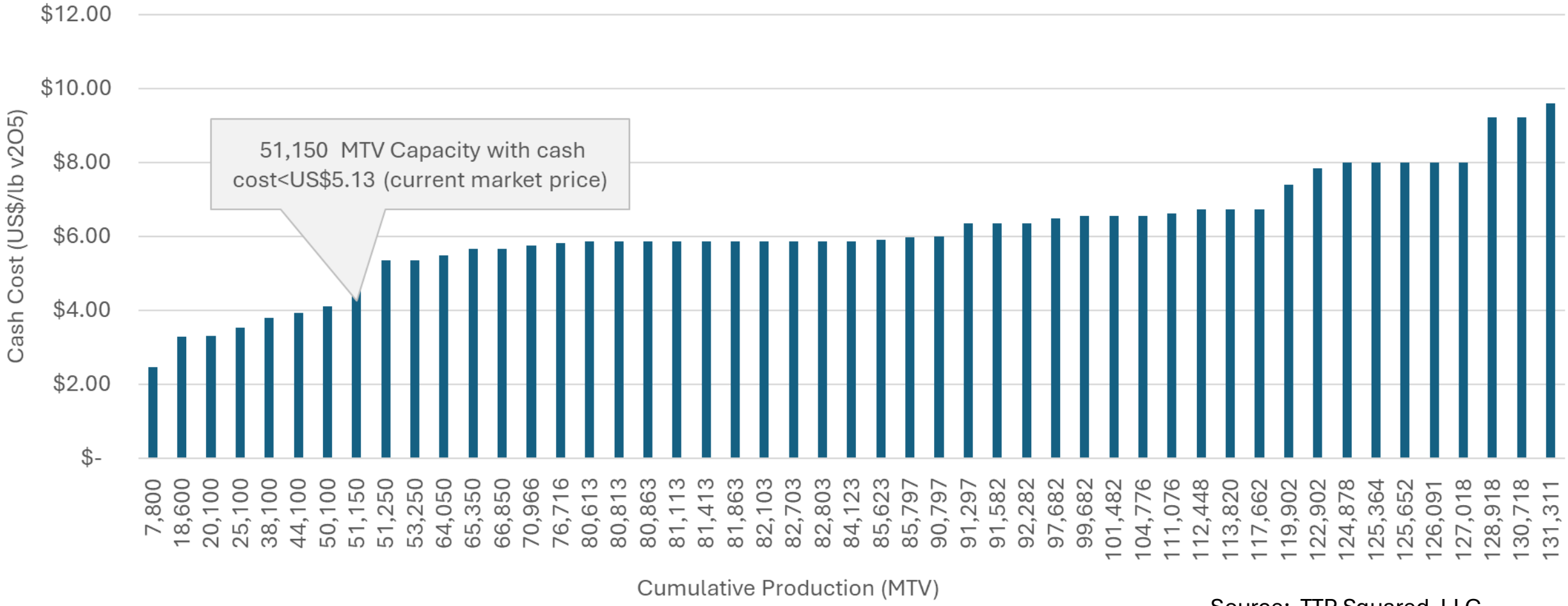
2024 Vanadium Cash Cost Curve

Production Volume 136,000 MTV



Source: TTP Squared, LLC

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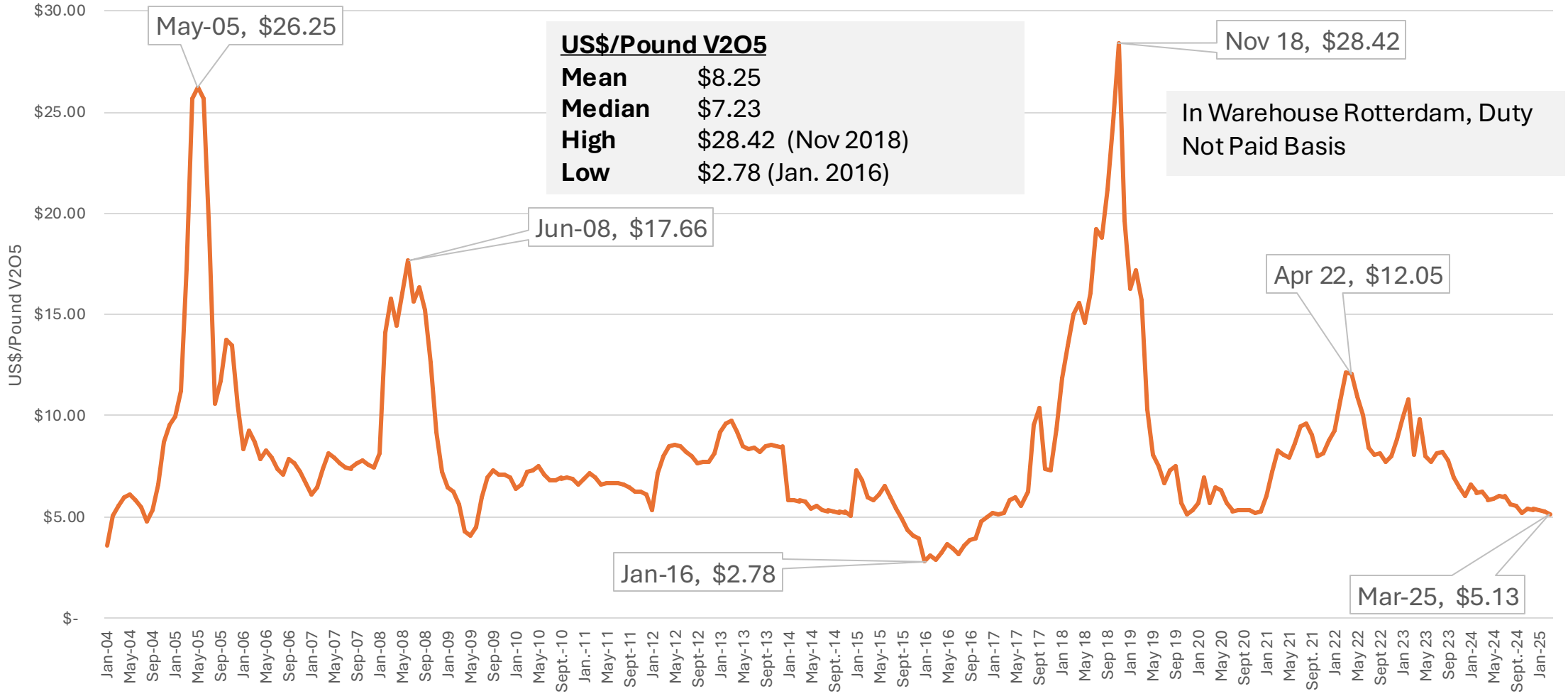
Metal Bulletin V2O5 Monthly Midpoint Average Nominal Price
Jan. 2004 - Mar. 2025



Source: Fastmarkets, TTP Squared, LLC

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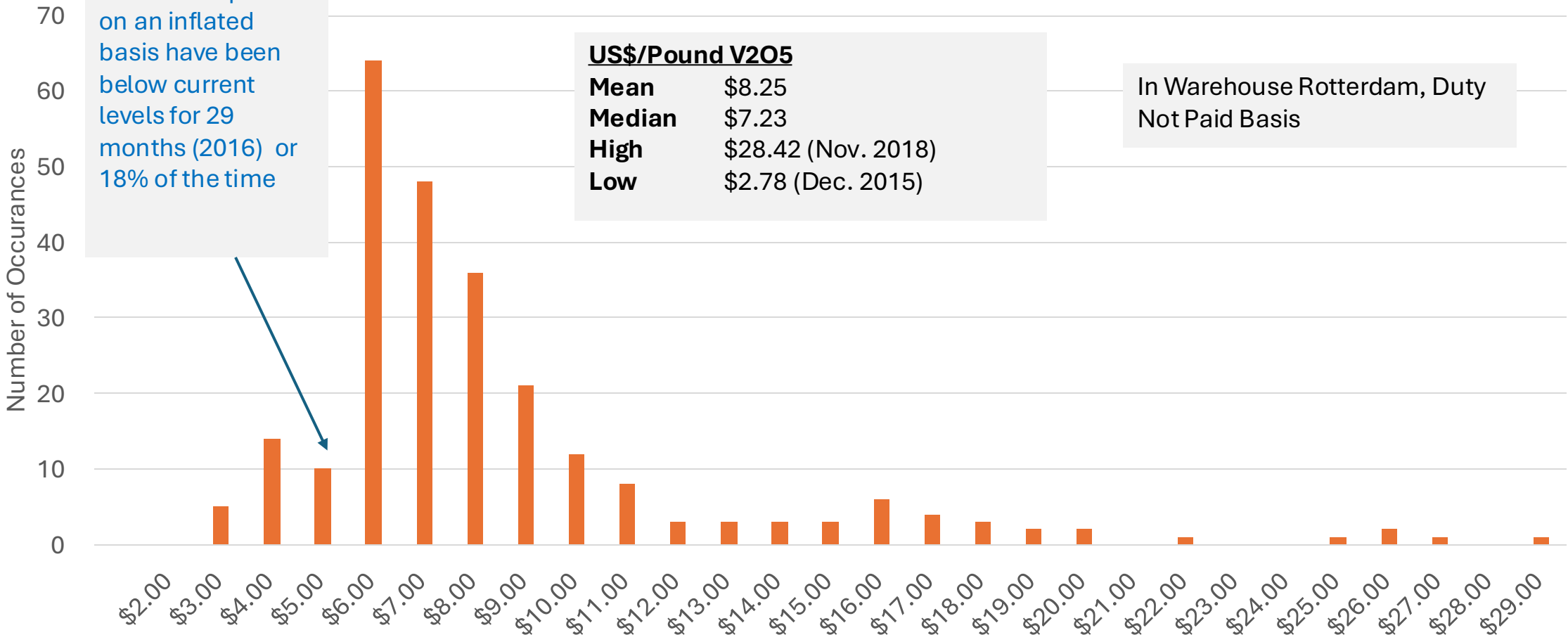
V2O5 Nominal Price Distribution Chart
Jan. 2004 - Mar. 2025

Since January 2004 V2O5 prices on an inflated basis have been below current levels for 29 months (2016) or 18% of the time

US$/Pound V2O5

Mean	$8.25
Median	$7.23
High	$28.42 (Nov. 2018)
Low	$2.78 (Dec. 2015)

In Warehouse Rotterdam, Duty Not Paid Basis



Source: Fastmarkets, TTP Squared, LLC

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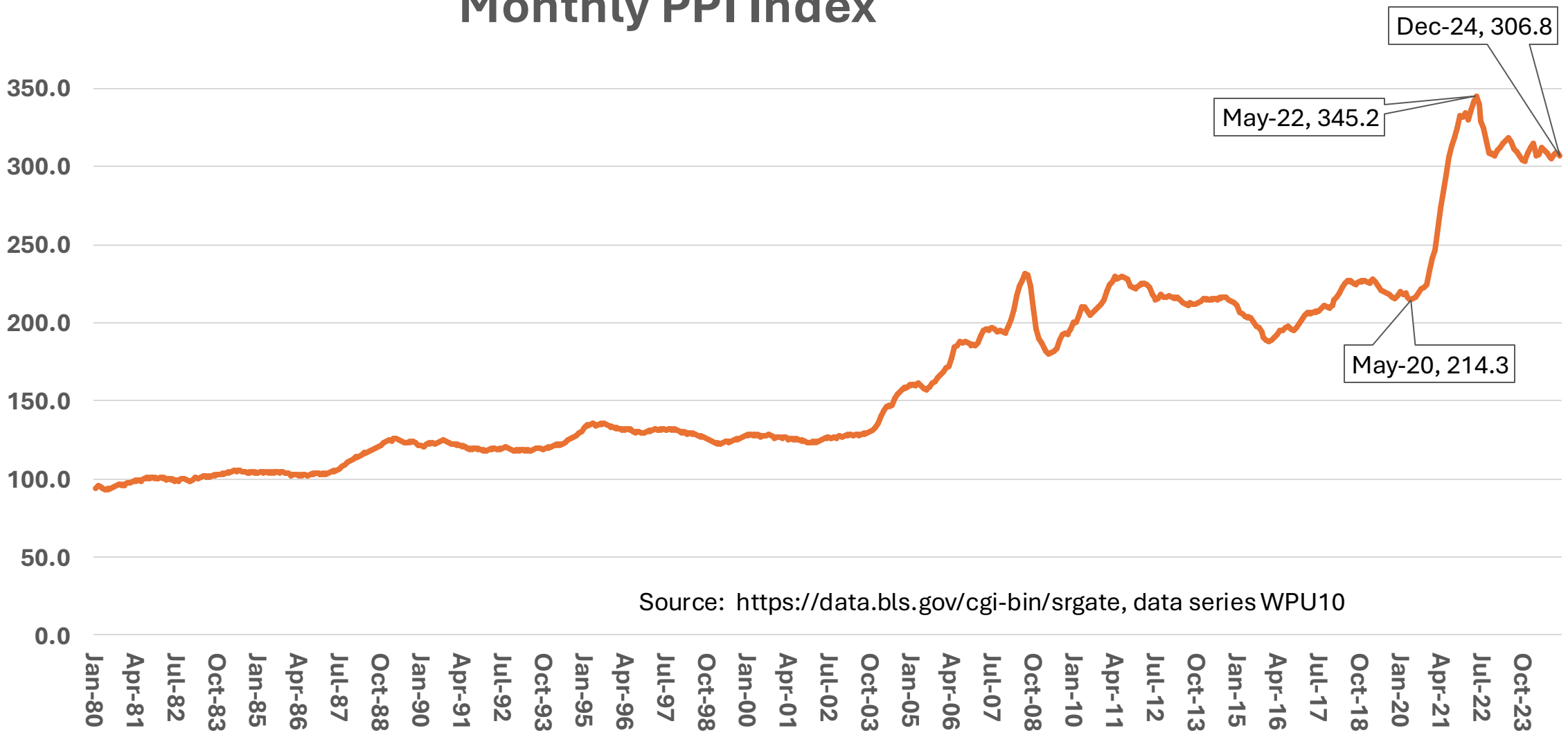
Monthly PPI Index



Source: https://data.bls.gov/cgi-bin/srgate, data series WPU10

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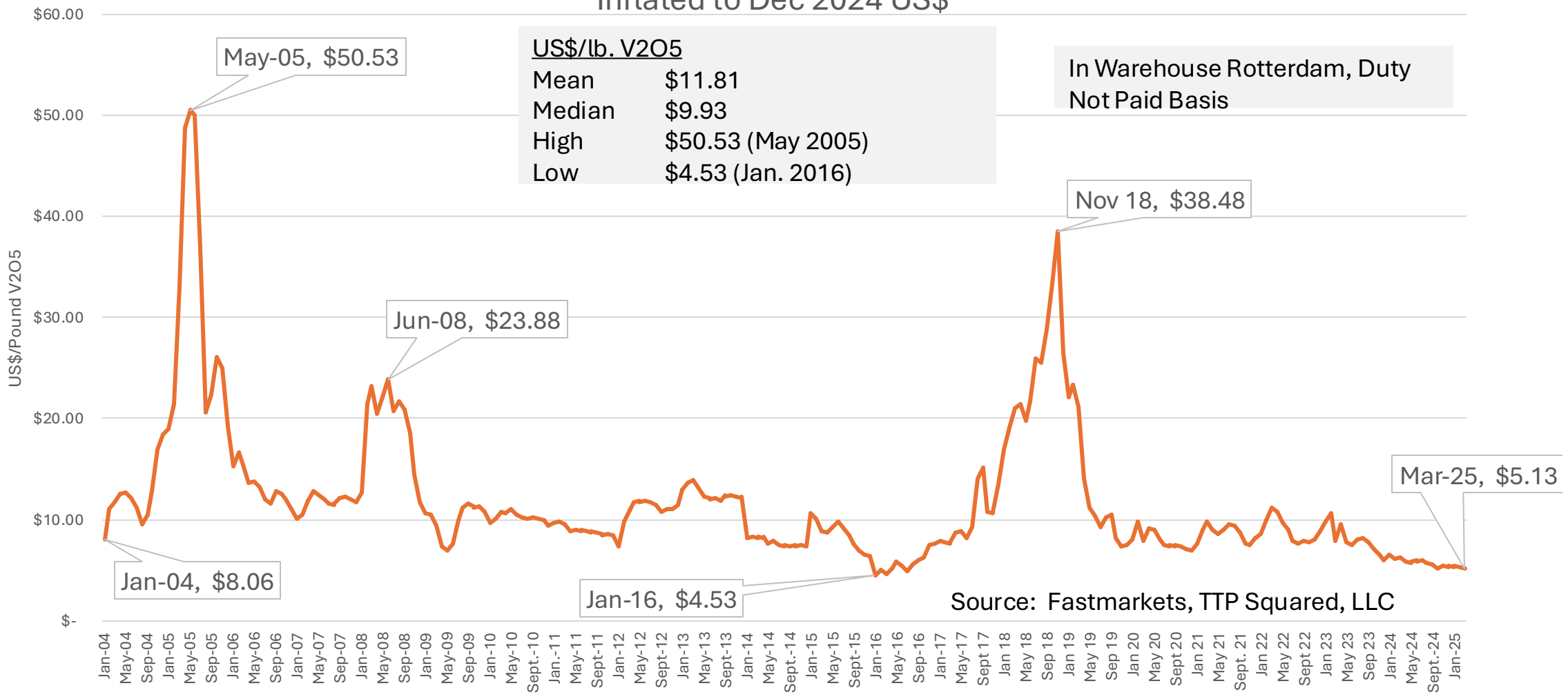
Metal Bulletin V2O5 Monthly Midpoint Average Real Price
Jan. 2004 - Mar. 2025
Inflated to Dec 2024 US$



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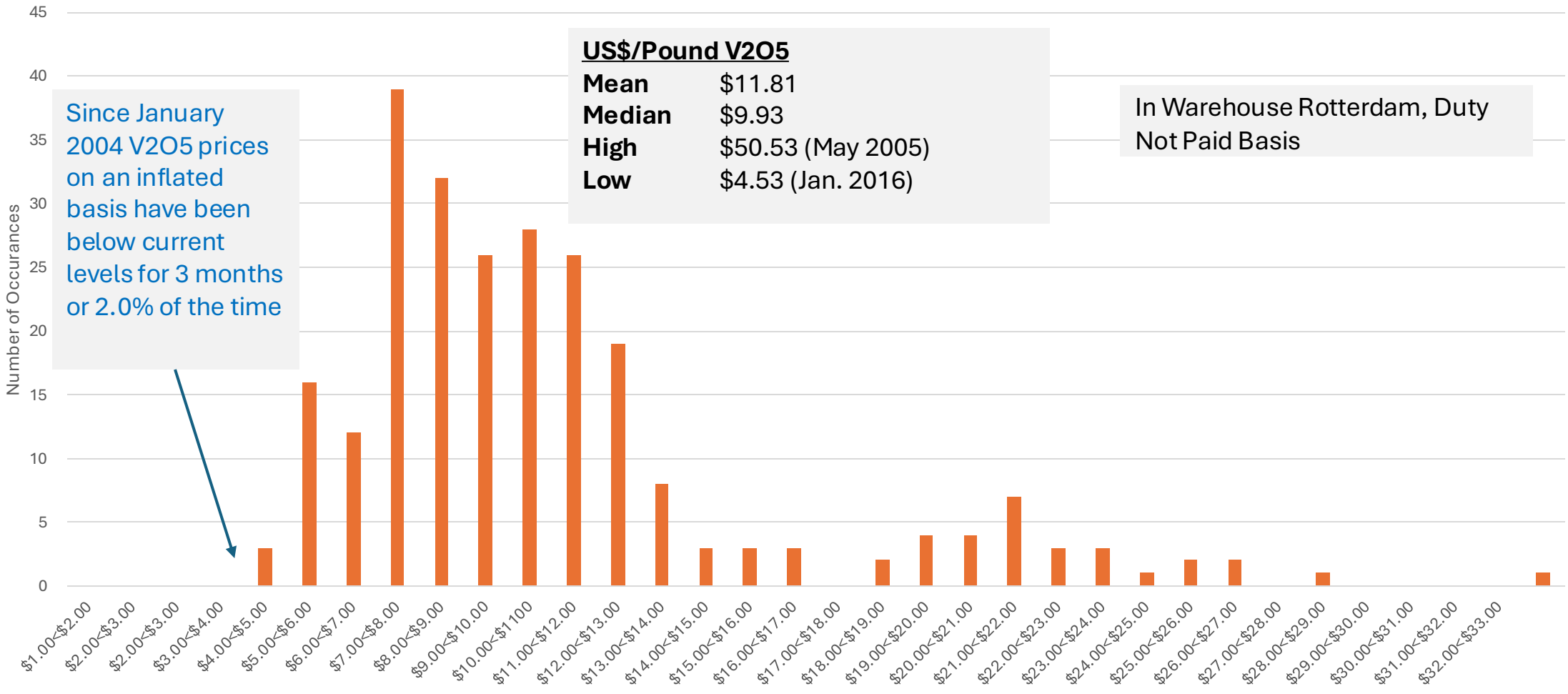
V2O5 Real Price Distribution Chart
Jan. 2004 - Mar. 2025
Inflated to Dec 2024 US$



Since January 2004 V2O5 prices on an inflated basis have been below current levels for 3 months or 2.0% of the time

US$/Pound V2O5

Mean	$11.81
Median	$9.93
High	$50.53 (May 2005)
Low	$4.53 (Jan. 2016)

In Warehouse Rotterdam, Duty Not Paid Basis

Source: Fastmarkets. TTP Squared, LLC

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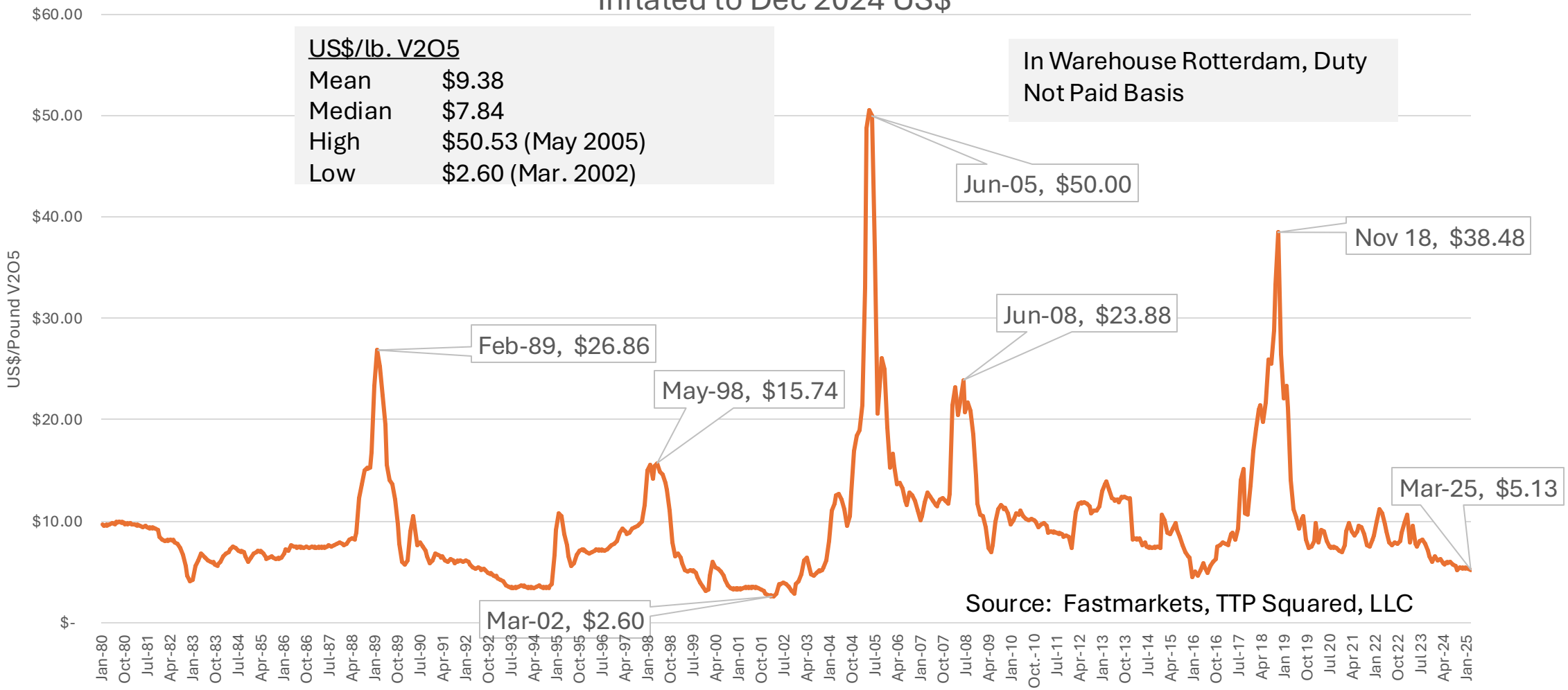
Metal Bulletin V2O5 Monthly Midpoint Average Real Price
Jan. 1980 - Mar. 2025
Inflated to Dec 2024 US$



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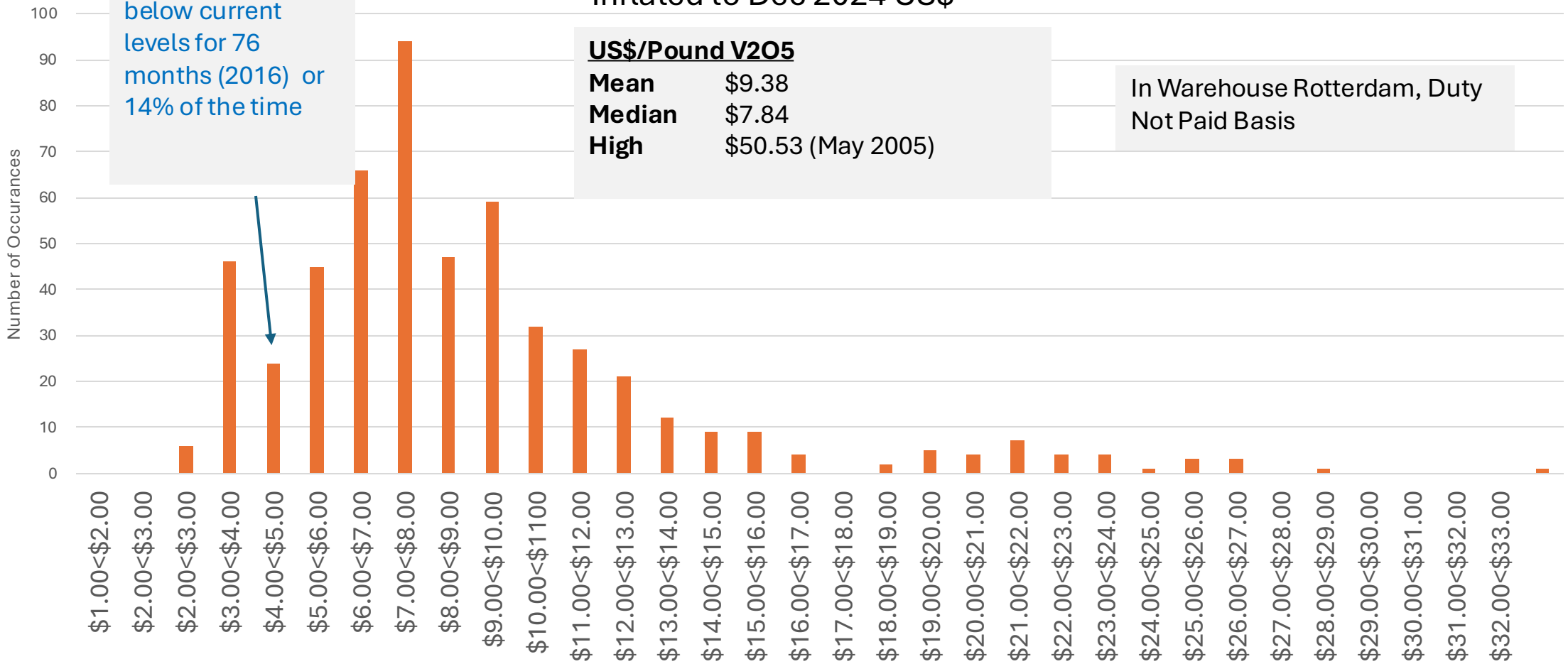
Since January 2004 V2O5 prices on an inflated basis have been below current levels for 76 months (2016) or 14% of the time

V2O5 Real Price Distribution Chart
Jan. 1980 - Mar. 2025
Inflated to Dec 2024 US$

US$/Pound V2O5

Mean	$9.38
Median	$7.84
High	$50.53 (May 2005)

In Warehouse Rotterdam, Duty Not Paid Basis



Source: Fastmarkets. TTP Squared, LLC