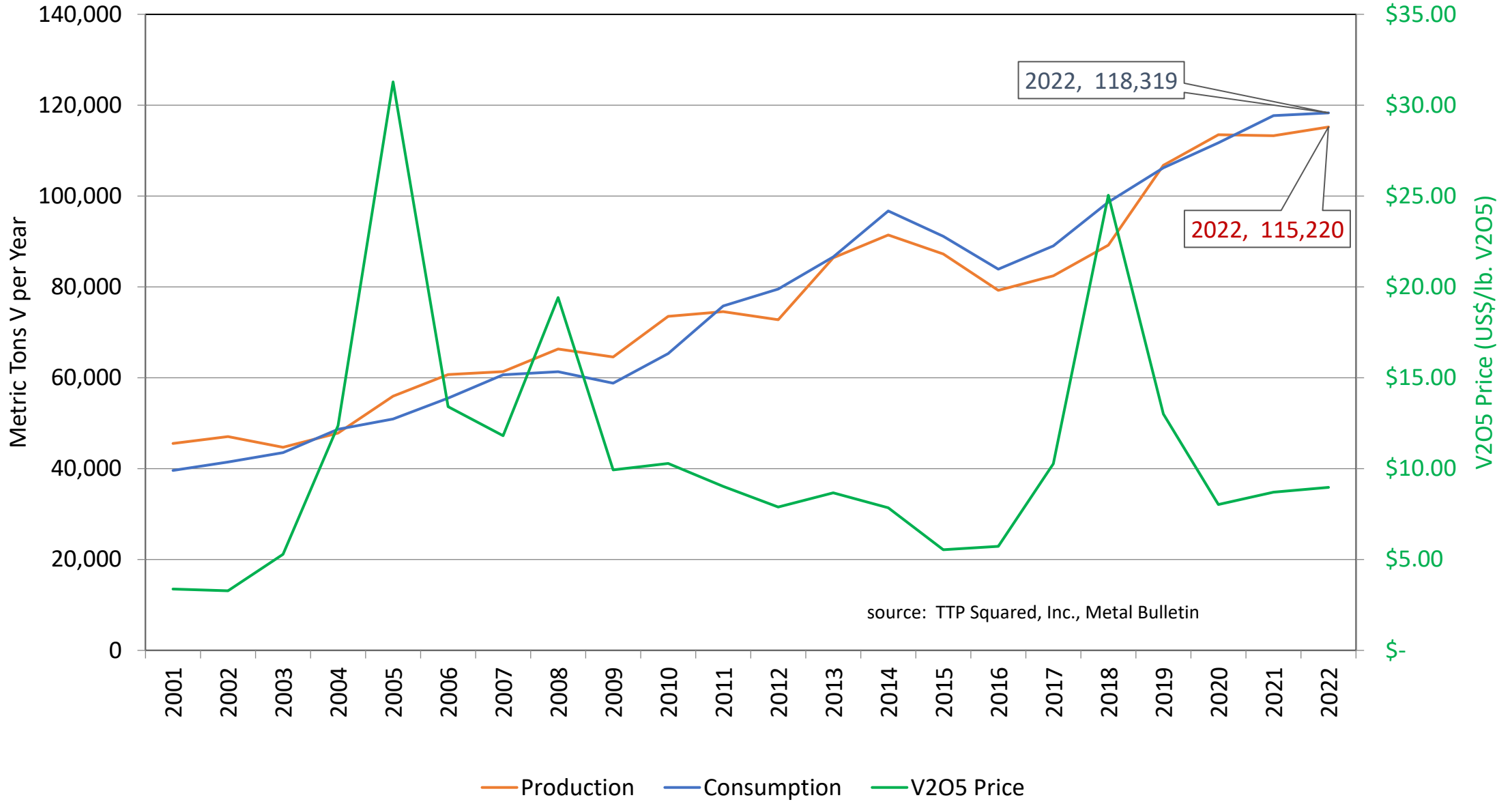


Vanadium Market Fundamentals

Terry Perles
US Vanadium, LLC
TTP Squared, Inc.

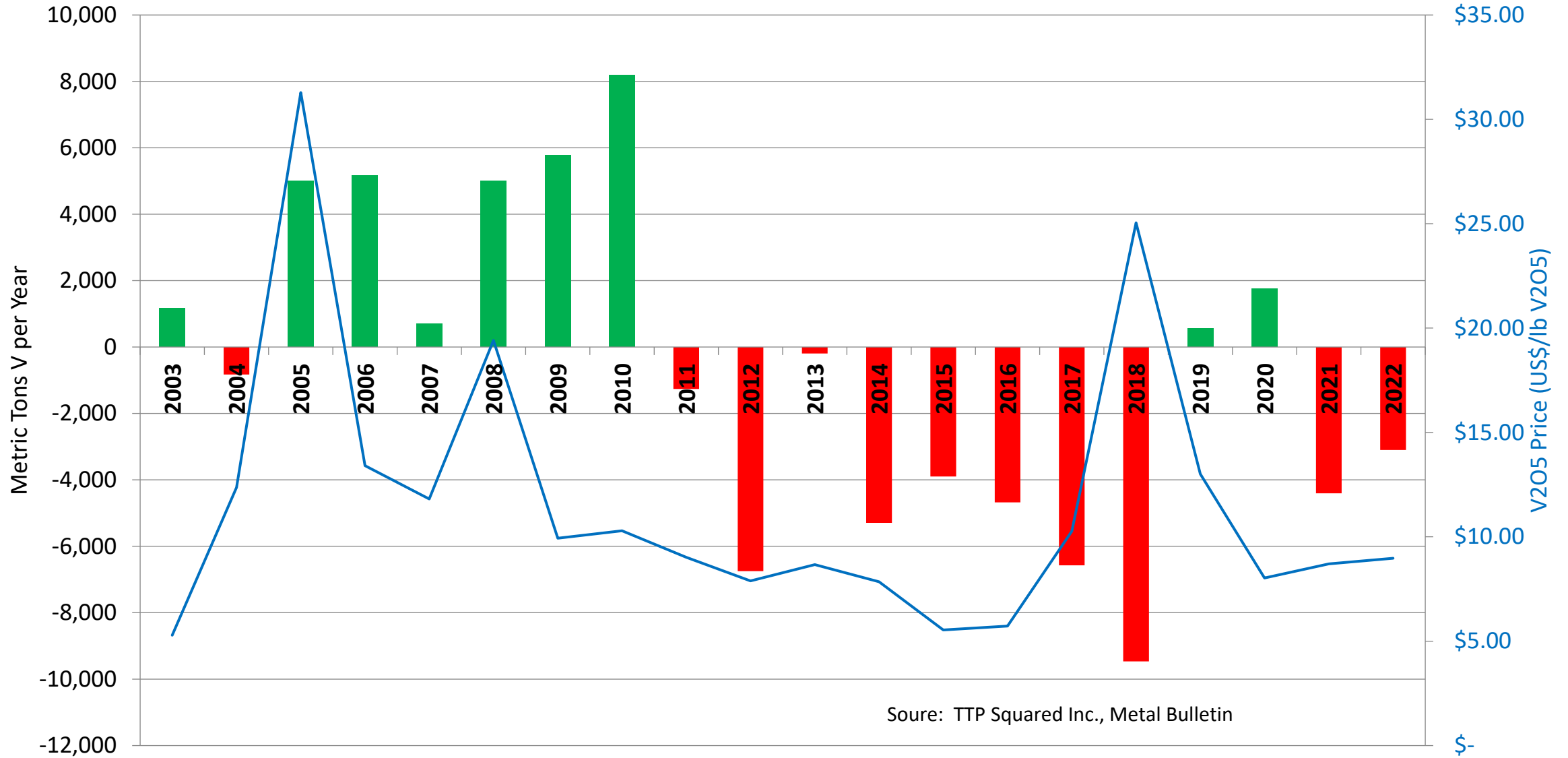
V Consumption and Production



source: TTP Squared, Inc., Metal Bulletin

Annual Vanadium Inventory Change

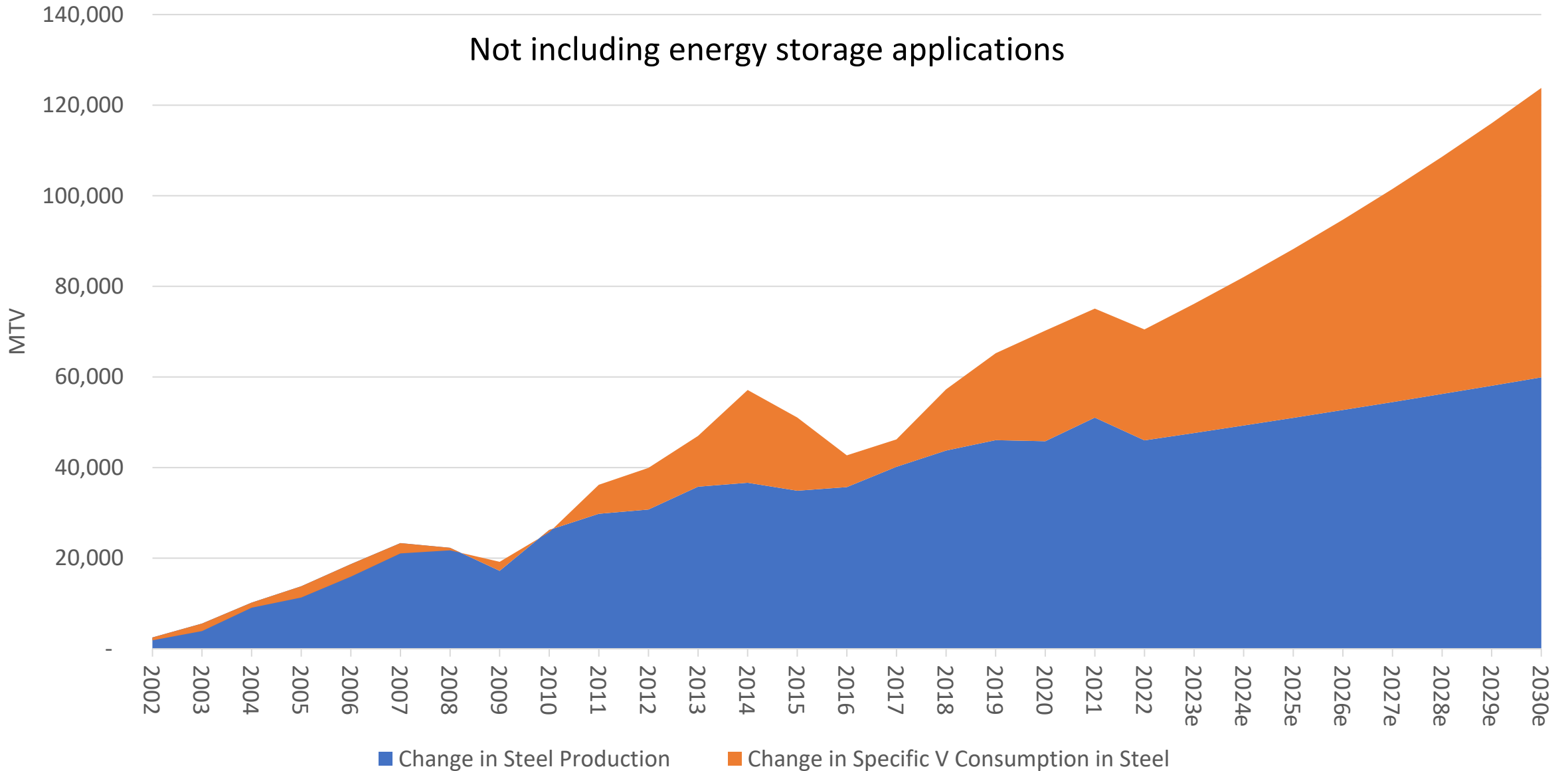
Price inflated to Nov. 2022 US\$



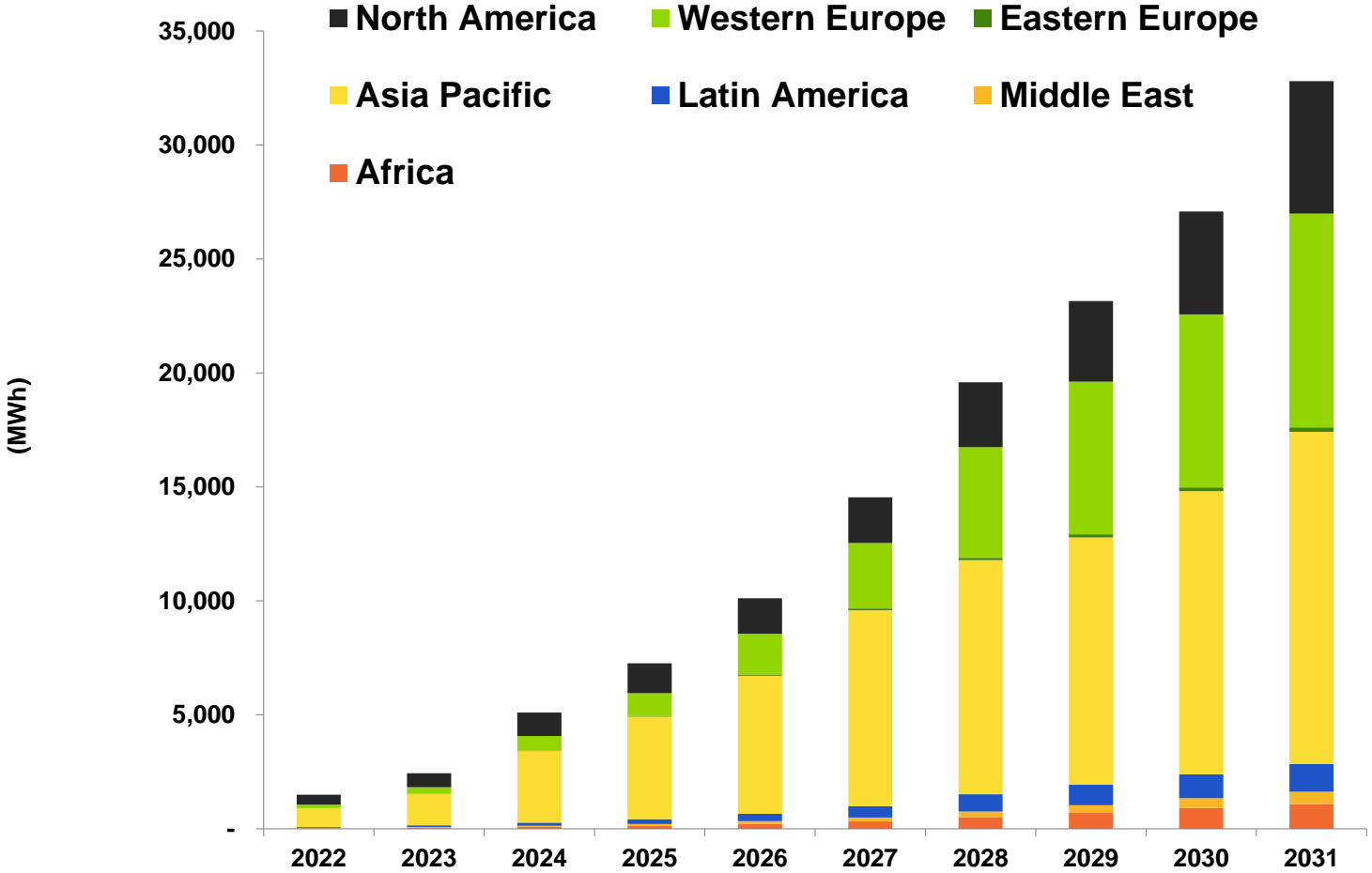
Source: TTP Squared Inc., Metal Bulletin

Sources of New Demand 2002-2030

Not including energy storage applications

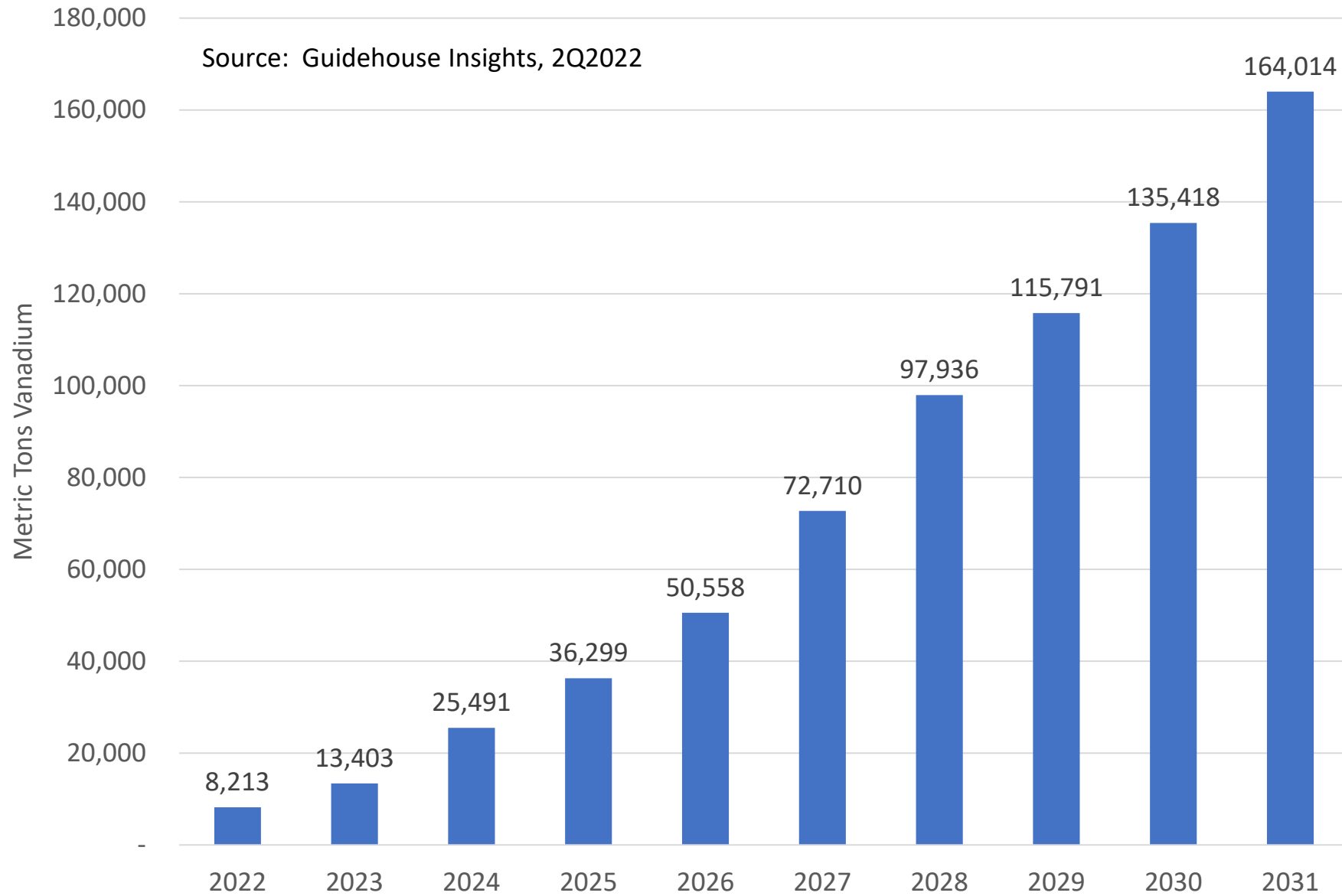


Annual Installed Utility and Commercial and Industrial VRFB Deployment Energy Capacity by Region, All Application Segments, World Markets: 2022-2031



Source: Guidehouse Insights, 2Q2022

Vanadium Demand in VRFB Systems



VRFB vs Lithium-ion Economics

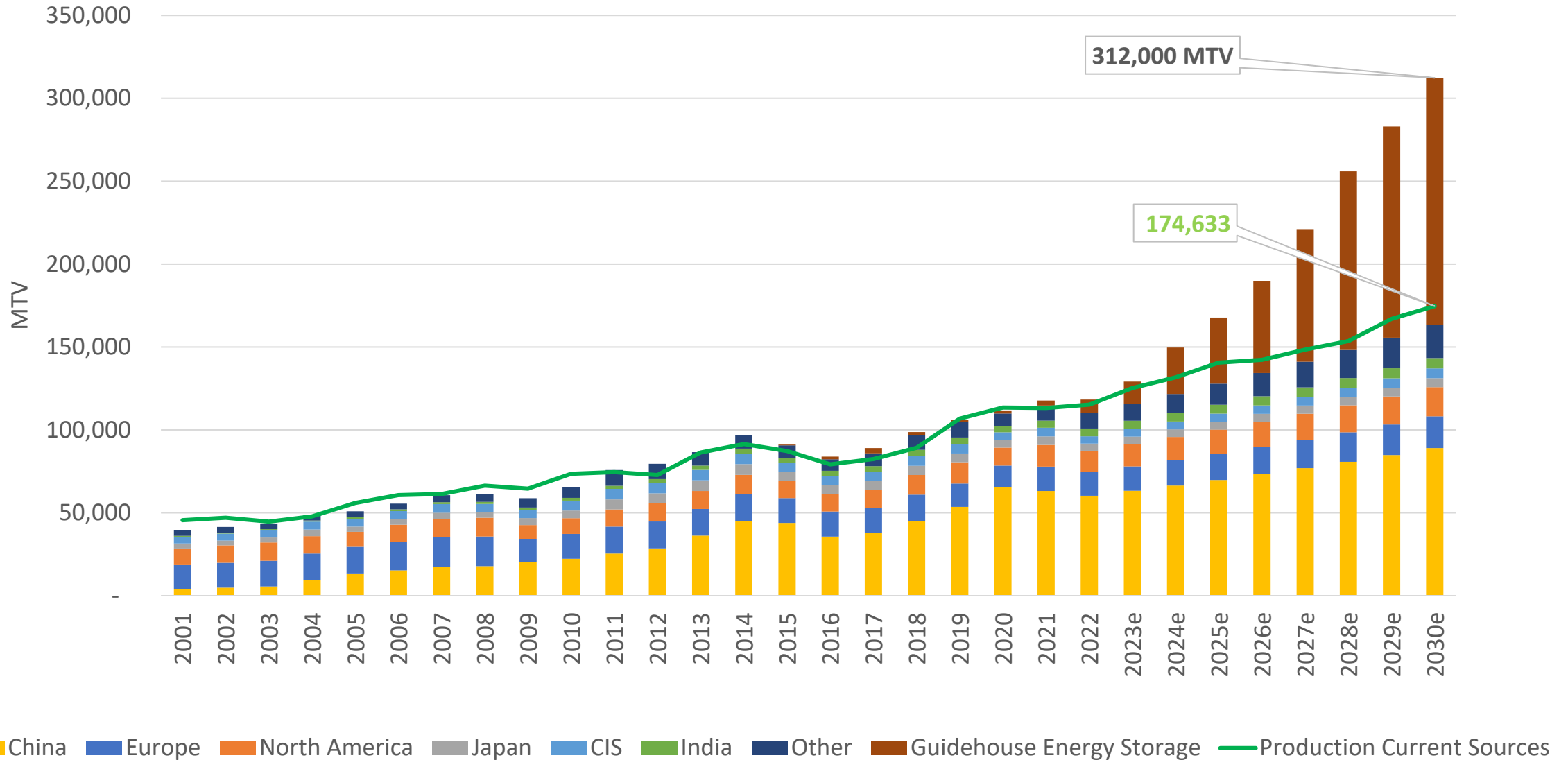
Head to Head Comparison: Lifetime Costs of a 3 MW, 8 Hour Duration System

		Cost Projections (\$ per KWhr)	Li ion	VRFB
CAPEX	DC System (cells, module, racking, BMS)		\$199	\$91
	Vanadium		\$0	\$210
	Containerization and Fire Suppression		\$31	\$0
	Initial Overbuild		\$23	\$0
	TOTAL		\$253	\$301
OPEX (NPV)	Electricity		\$138	\$177
	O&M		\$51	\$27
	Replacement and ongoing augmentation		\$106	\$0
	Liability insurance		\$44	\$5
	End of life disposal (recovery)		\$3	(\$105)
	TOTAL		\$340	\$104
Total CAPEX + OPEX			\$593	\$405

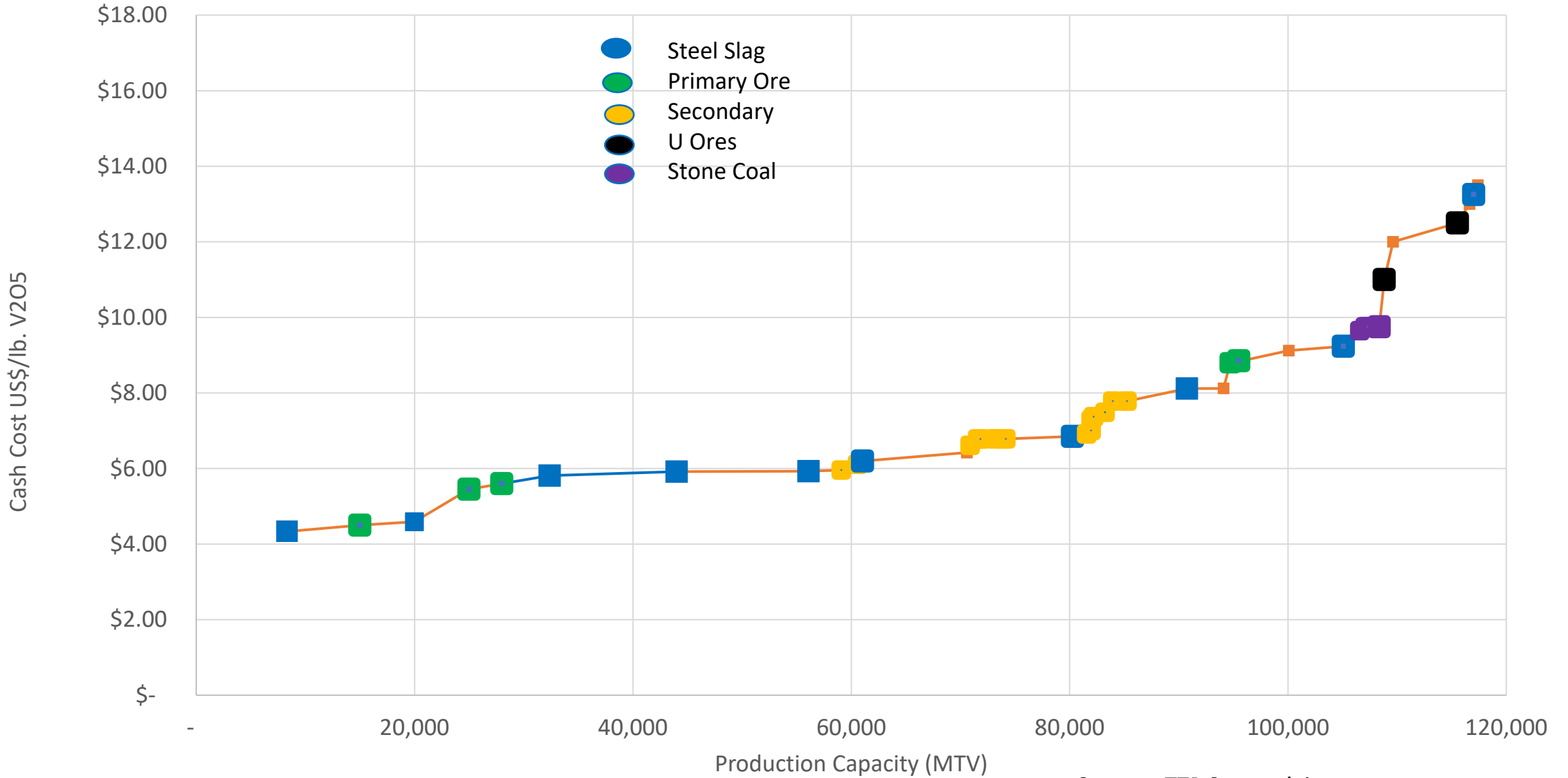
Lithium-ion Weaknesses

- Power and energy coupled, creating a linear cost curve
- Experience energy loss with age and every cycle
- Primarily focused on automotive
i.e. R&D \$ toward power not cycles
- Heat causes fires and in extreme cases explosions

Vanadium Production/Consumption Forecast



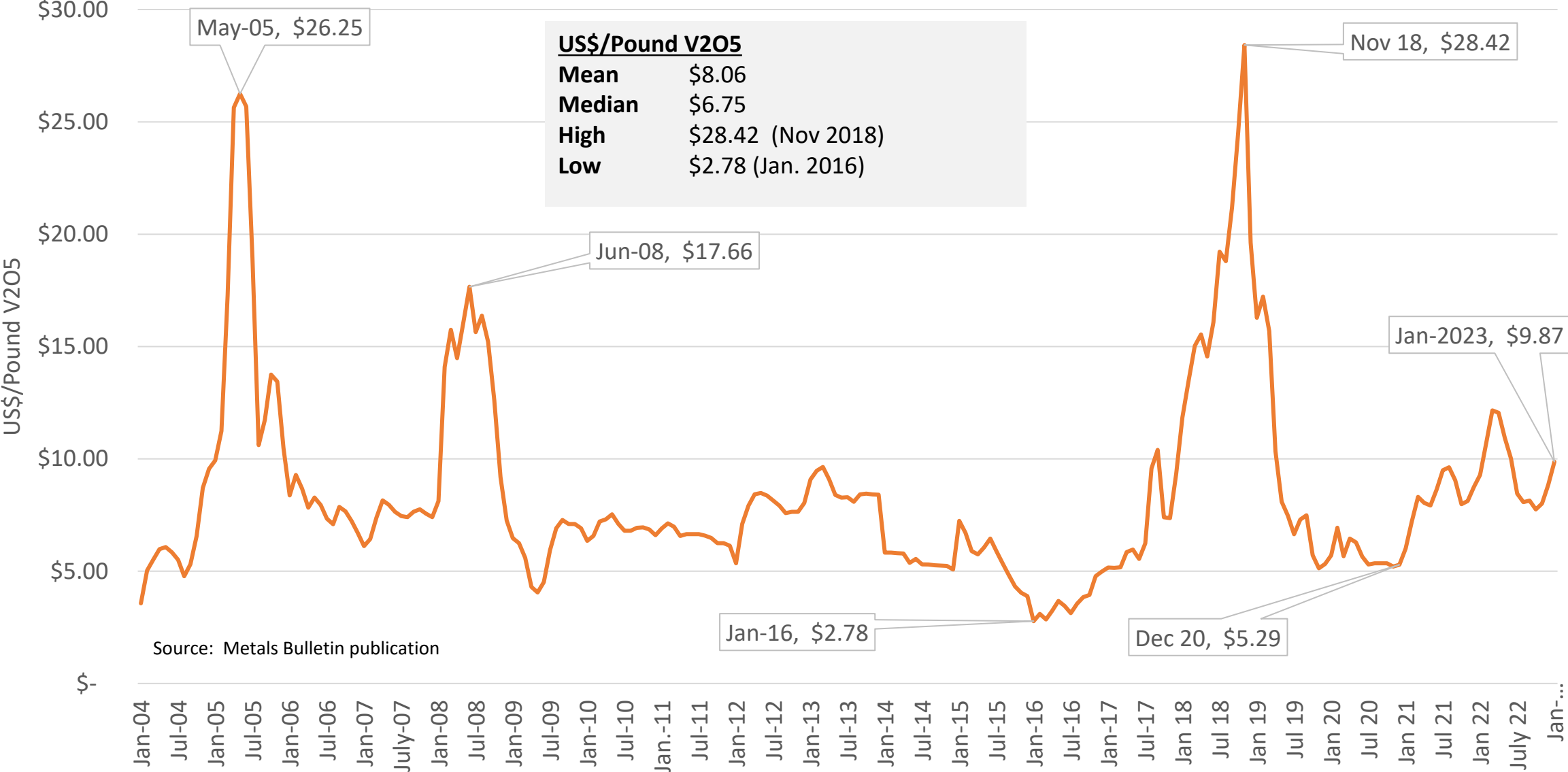
2022 V2O5 Cash Cost Curve



Source: TTP Squared, inc.

Metal Bulletin V2O5 Monthly Midpoint Average Nominal Price

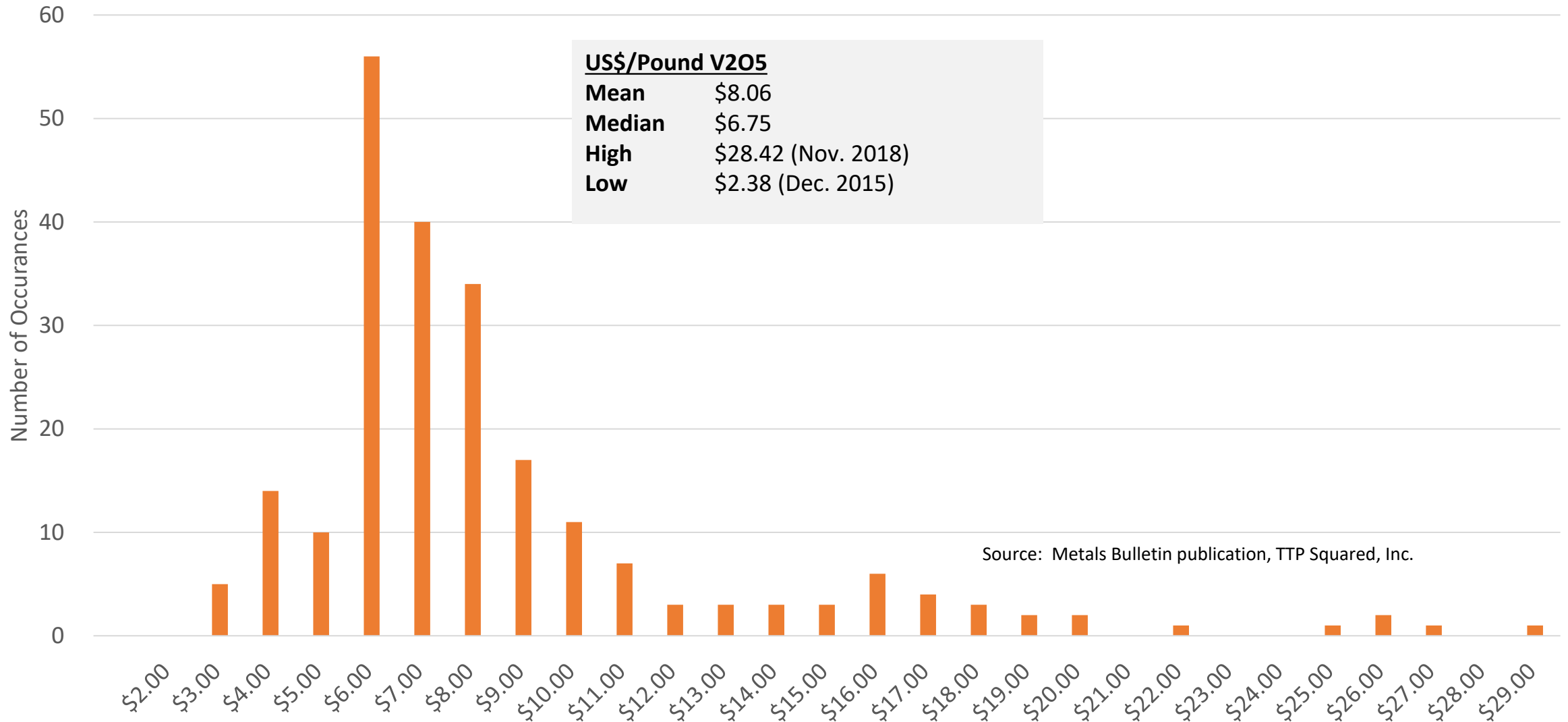
Jan. 2004 - Jan. 2023



Source: Metals Bulletin publication

V2O5 Nominal Price Distribution Chart

Jan. 2004 - Nov. 2022



<u>US\$/Pound V2O5</u>	
Mean	\$8.06
Median	\$6.75
High	\$28.42 (Nov. 2018)
Low	\$2.38 (Dec. 2015)

Source: Metals Bulletin publication, TTP Squared, Inc.

Metal Bulletin V2O5 Monthly Midpoint Average Real Price

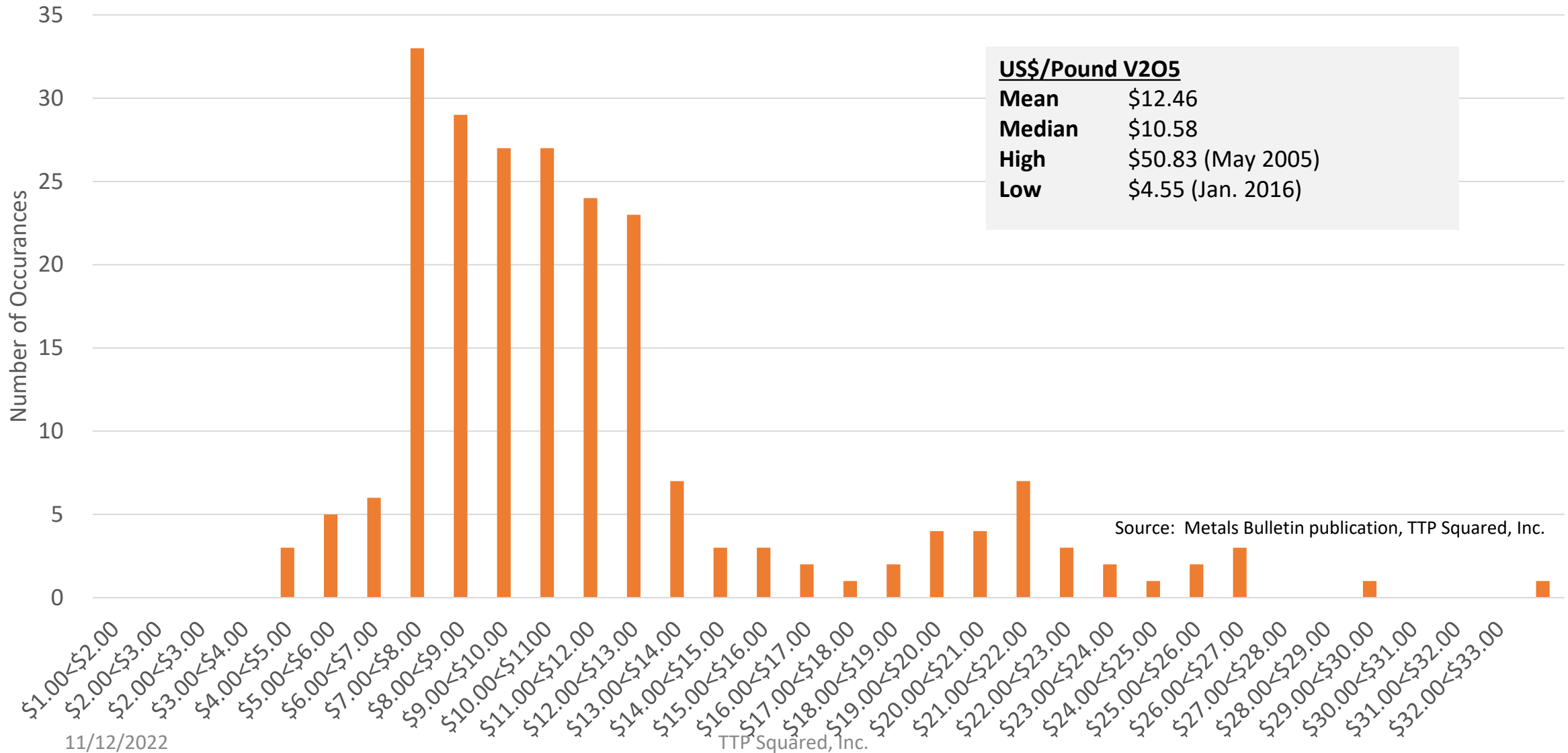
Jan. 2004 - Nov. 2022

Inflated to Nov. 2022 US\$



V205 Real Price Distribution Chart

Jan. 2004 - Nov. 2022
Inflated to Nov. 2022 US\$

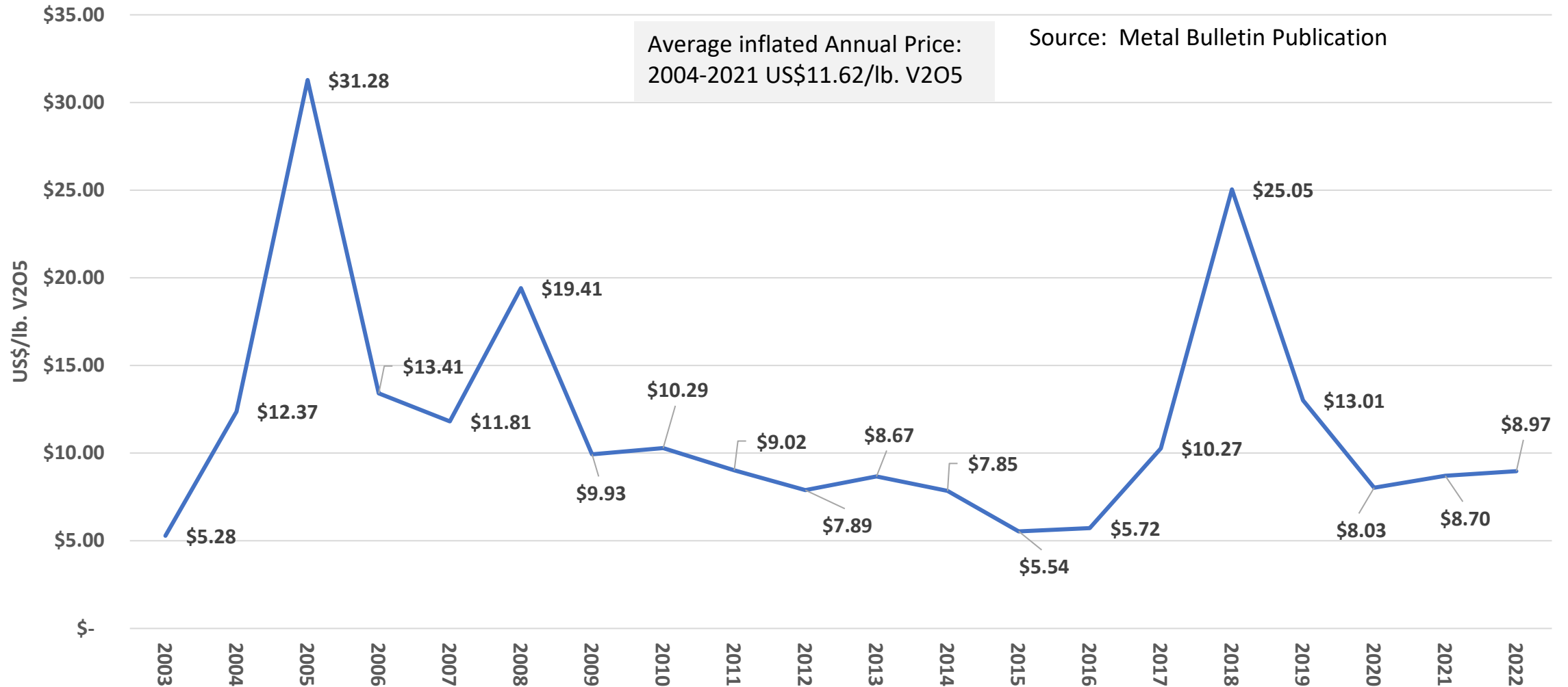


US\$/Pound V205	
Mean	\$12.46
Median	\$10.58
High	\$50.83 (May 2005)
Low	\$4.55 (Jan. 2016)

Source: Metals Bulletin publication, TTP Squared, Inc.

Annual Inflated V2O5 Price

Inflated to Nov. 2022 US\$



Summary

- Vanadium consumption will grow in the coming years as a result of the use of vanadium in energy storage applications including vanadium redox flow battery systems. There are wide variances in the projected rate of growth of vanadium in energy storage applications in the next 10 years
- Consumption of vanadium in the steel industry will continue to see moderate growth as global specific vanadium consumption rates continue to increase as a result of the economic benefit of replacing lower strength steels with high strength low alloy steels in load bearing applications

Summary

- Assuming even modest growth in vanadium consumption in energy storage applications, the industry will be challenged to meet surging demand in the coming decade.
- Long term inflated V2O5 historical prices are in the range of US\$9.00-\$12.00/lb. V2O5.
- The cash cost of the last incremental units required to satiate demand in 2022 is above US\$12.00/lb. V2O5.



US VANADIUM

U.S. Vanadium LLC produces and sells a range of specialty vanadium chemicals, including the highest-purity Vanadium Pentoxide (V_2O_5) in the world.

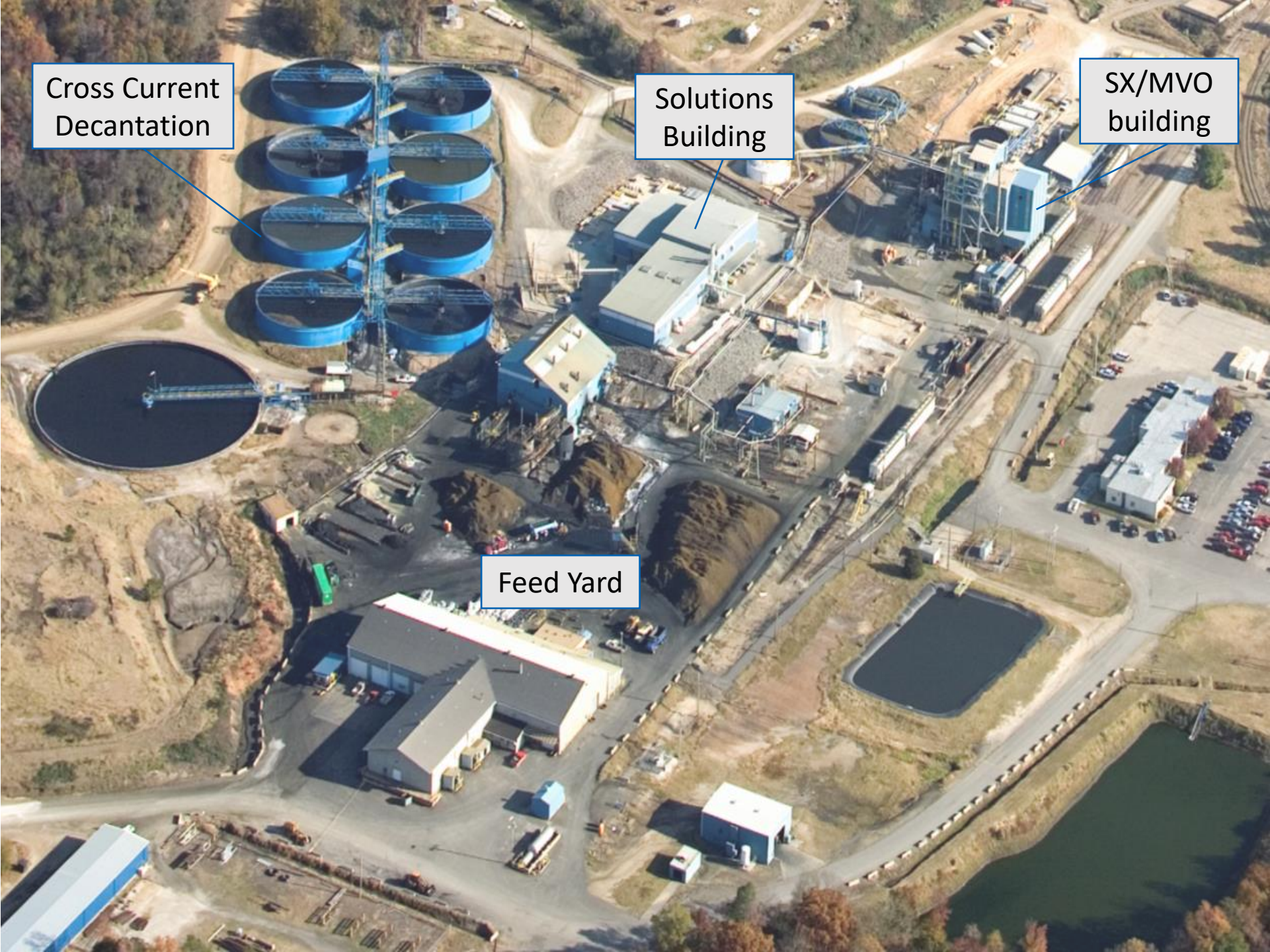


Cross Current
Decantation

Solutions
Building

SX/MVO
building

Feed Yard



Feed Stock Sources

FEEDSTOCK	SOURCE	PROPERTIES	V ₂ O ₅	H ₂ O
Flexicoke/Coke	Produced at an oil refinery as part of the refining process. Residual after the production of syngas.	Fine light black powder, very slick when wet, dusting an issue and must be controlled	6-14%	30-40%
Fly Ash	Typically produced at a power plant as a result of burning oil to make power. Usually collected dry from the exhaust gases, but can be stored wet in ponds	Typically a fine, light powder, black in color but ranges from brown to grey. Can be very wet if removed from collection ponds	2-30%	1-65%
Petcoke Cinder	Typically produced at a gasification unit to produce a syngas then cinder is collected at the bottom of the gasifier	Similar to fly ash but not light and powdery. Heavy almost grainy. Usually black in color.	5-30%	1-10%
Boiler Slag / Bottom Ash	Produced in boilers when burning oil as a result of metallic material fusing after exposure to high heat for an extend period of time.	Looks like rocks. Very hard with large chunks. If crushed, the exposed surface will be shiny due to high metals content	30-60%	2-5%
Steel Slag	Byproduct from the production of pig iron in the steel production process when processing vanadium bearing iron ore.	Brown solid	10-24%	3-5%
Slimes	Typically produced at a power plant as a result of burning oil to produce power.	Typically a wet mixture of very fine ash and water. In some cases it is a mix of bottom ash and slag	18-30%	20-40%
Maleic Catalyst	Catalyst used in the production of maleic anhydride	Light blue to white pellets or dust. High in phosphorous	40-60%	1-5%
Sulfuric Acid Catalyst	Catalyst used in the production of sulfuric acid	Yellow to white pellets. High in silica. Cannot be feed in residue or flexicoke circuit.	3-6%	5-10%

Oxide Specifications



Product Specification

Vanadium Pentoxide (V₂O₅) (High-Purity Granular)



CHEMISTRY

Major Elements		
	Min.	Max.
Vanadium (as V ₂ O ₅)	99.6%	
V ₂ O ₄		0.5%
Iron (Fe)		0.02%
Molybdenum (Mo)		0.025%
Potassium (K)		0.01%
Sodium (Na)		0.01%
Silicon (Si)		0.01%

PHYSICAL CHARACTERISTICS

Nominal Size	
U.S. No. 20 x down (850 μm x down)	
Physical Properties	
Melting Point:	1274 °F (690 °C)
Bulk Density:	75 - 82 lb/ft ³ (1.2 - 1.3 g/cc)
Specific Gravity:	Approx. 3.4
Appearance	
Yellow-Orange Powder	
Standard Packaging	
Super Sacks:	2,205 lbs. (1,000 kg)
55-Gallon Open-Head Steel Drum:	440 lbs. (200 kg)
12-Gallon Fibre Drum:	110 lbs. (50 kg)



Product Specification

Vanadium Trioxide (V₂O₃)



CHEMISTRY

Major Elements		
	Min.	Max.
Vanadium (as V ₂ O ₃)	119.5%	
Iron (Fe)		0.03%
Molybdenum (Mo)		0.05%
Potassium (K)		0.015%
Sodium (Na)		0.02%
Silicon (Si)		0.01%

PHYSICAL CHARACTERISTICS

Nominal Size	
U.S. No. 20 x down (850 μm x down)	
Physical Properties	
Melting Point:	3578 °F (1970 °C)
Bulk Density:	75 - 82 lb/ft ³ (1.2 - 1.3 g/cc)
Specific Gravity:	Approx. 4.8
Appearance	
Black Powder	
Standard Packaging	
Super Sacks:	2,205 lbs. (1,000 kg)
55-Gallon Open-Head Steel Drum:	440 lbs. (200 kg)
12-Gallon Fibre Drum:	110 lbs. (50 kg)

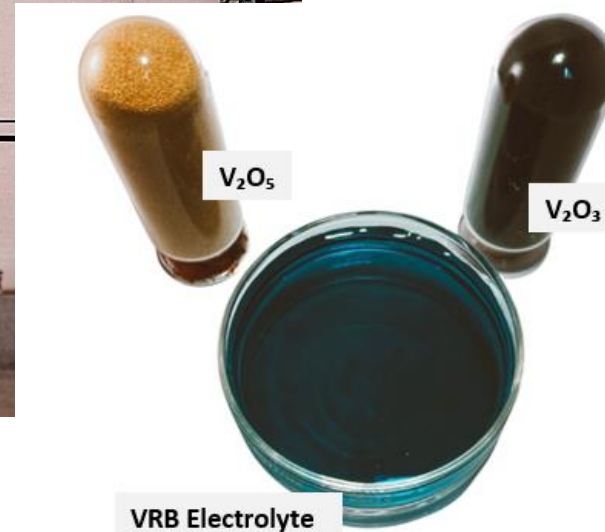
Halides and Solutions Building



Electrolyte Production



Electrolyte Storage



VRB Electrolyte

Thanks!

Terry Perles

Terry.perles@usvanadium.com

terry@ttpsquared.com

+1 412 897 3066