

Master Alloy Market Trends & Analysis

International Titanium Association Annual Meeting
Las Vegas, Nevada
October 10, 2018

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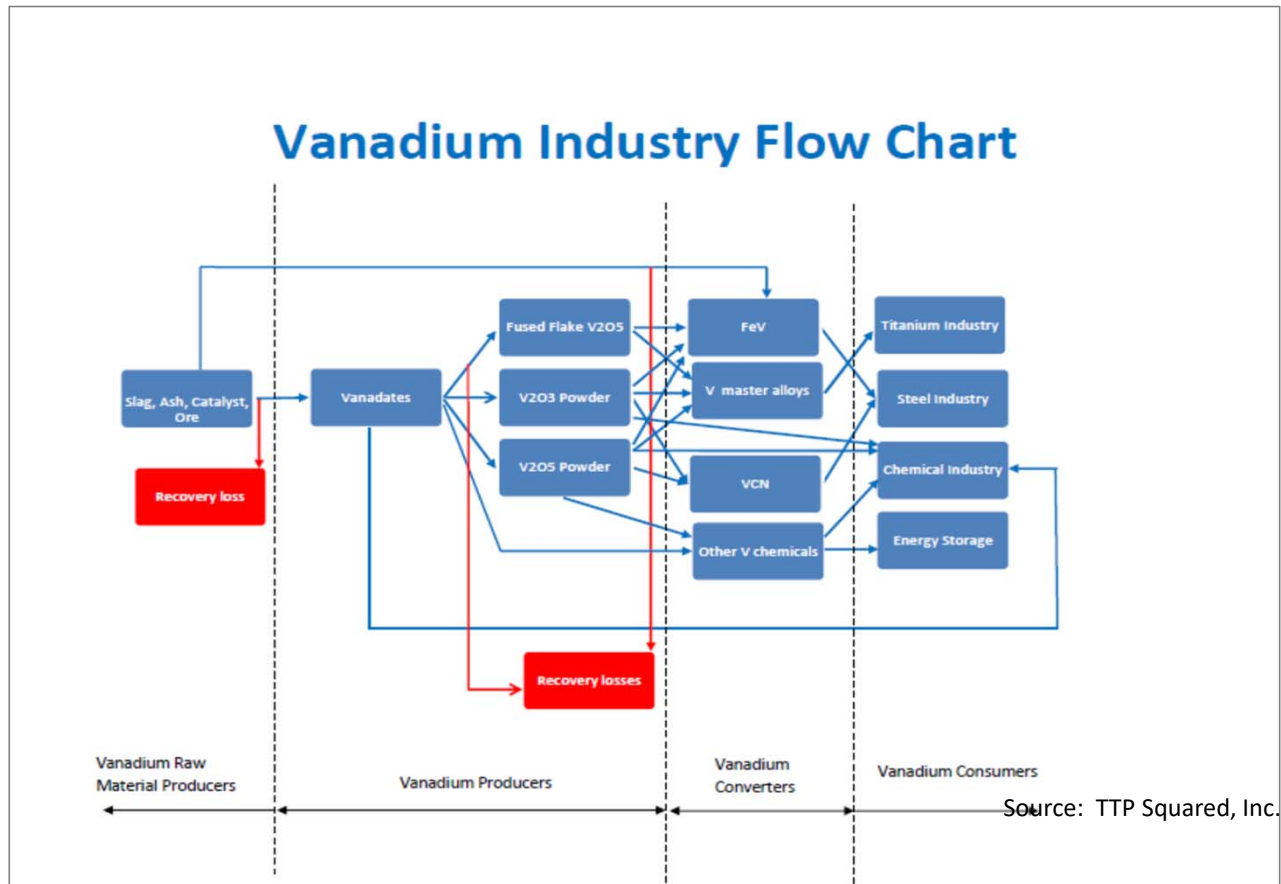
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Agenda

- Vanadium
 - Production
 - Consumption
 - Demand Drivers
 - Inventory Change
- Molybdenum
 - Production
 - Consumption
 - Inventory Change
- Role of Master Alloy Suppliers in the Ti Alloy Industry

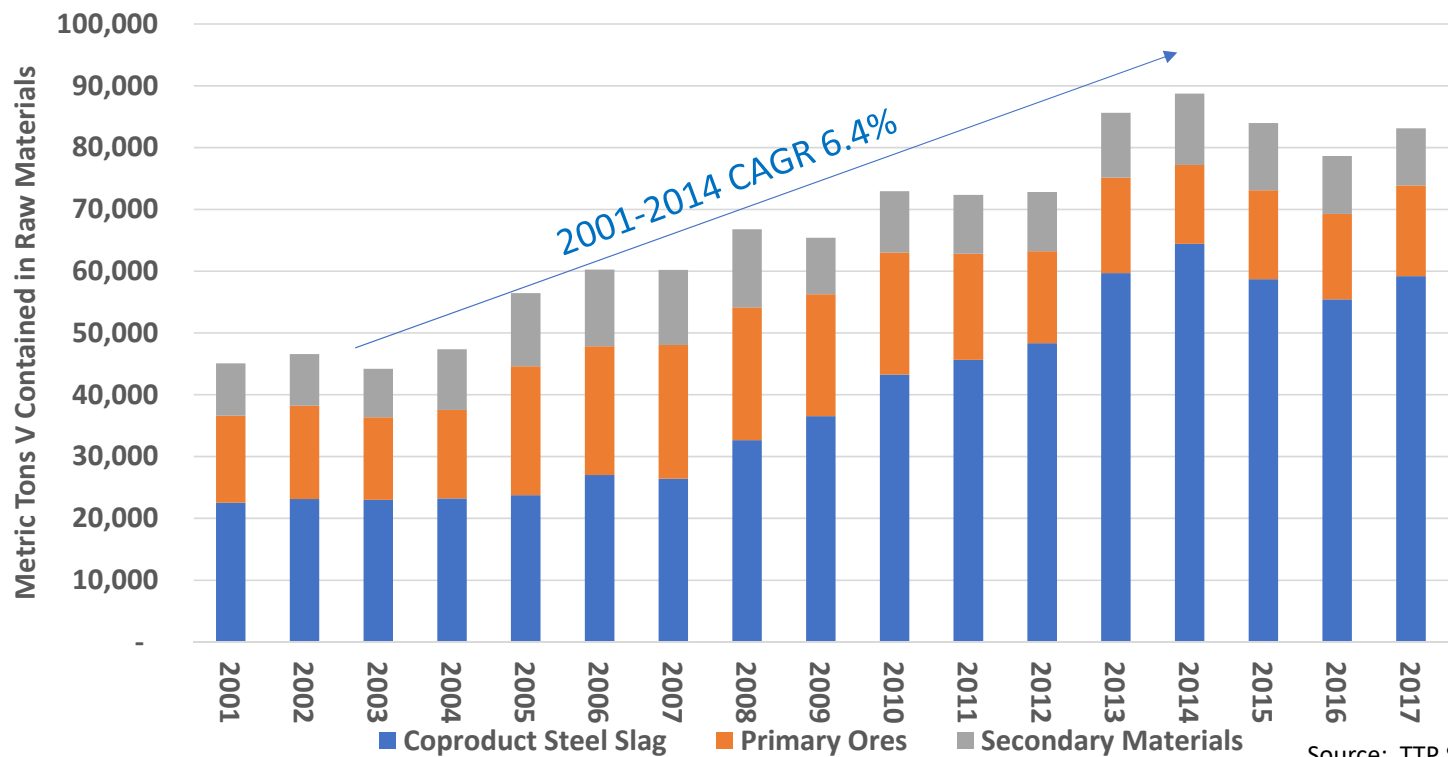
Vanadium Production

Definition of Production



Vanadium Production

Historical Production

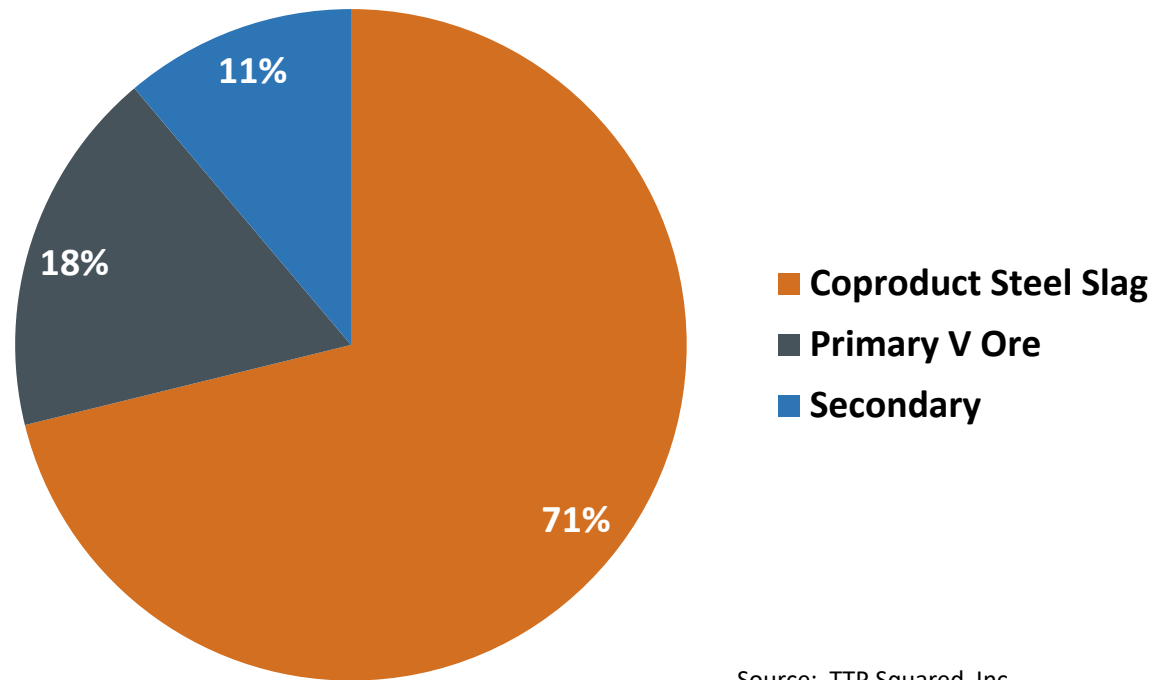


Source: TTP Squared, Inc.

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Vanadium Production

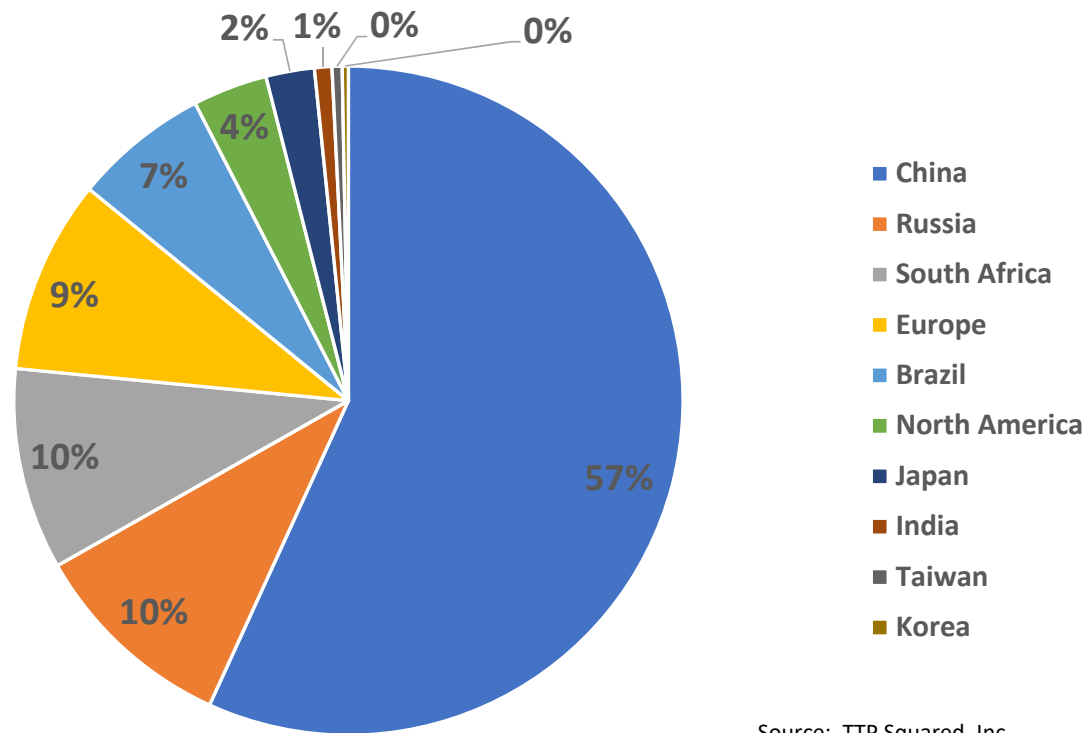
Sources of Raw Material 2017



Source: TTP Squared, Inc.

Vanadium Production

Production by Country 2017

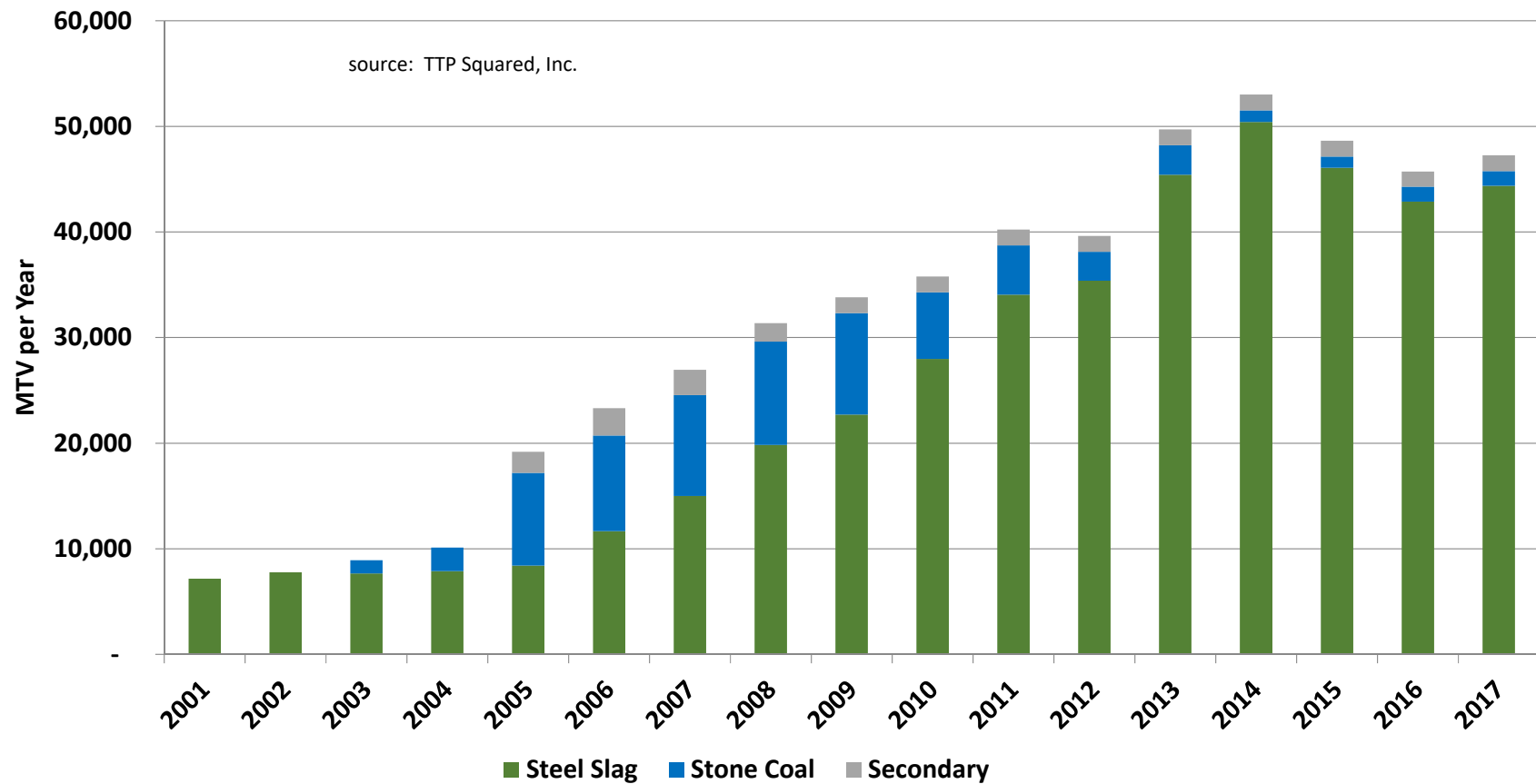


Source: TTP Squared, Inc.

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Vanadium Production

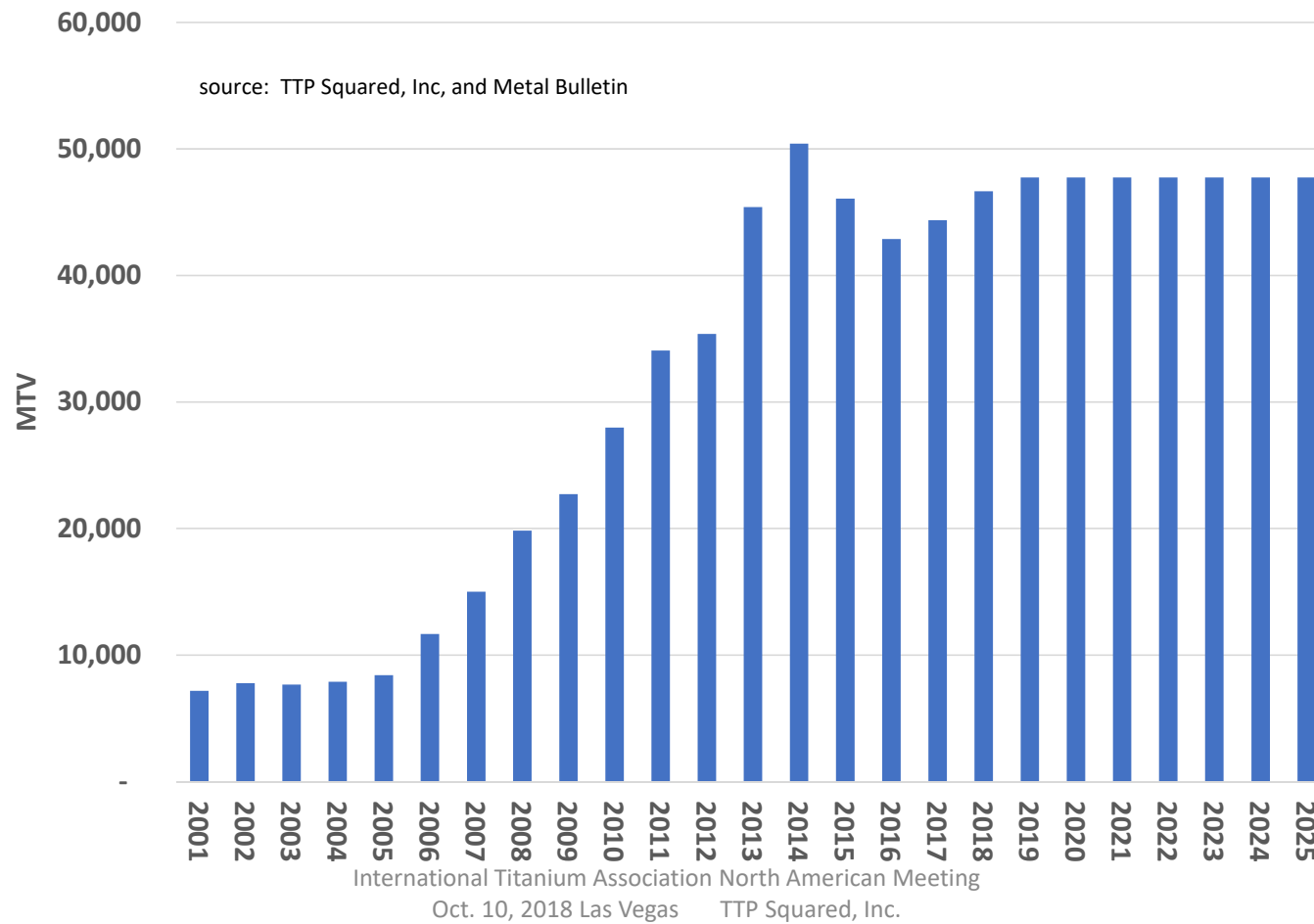
Chinese Production by Raw Material Source



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Vanadium Production

Production from Chinese Steel Slag

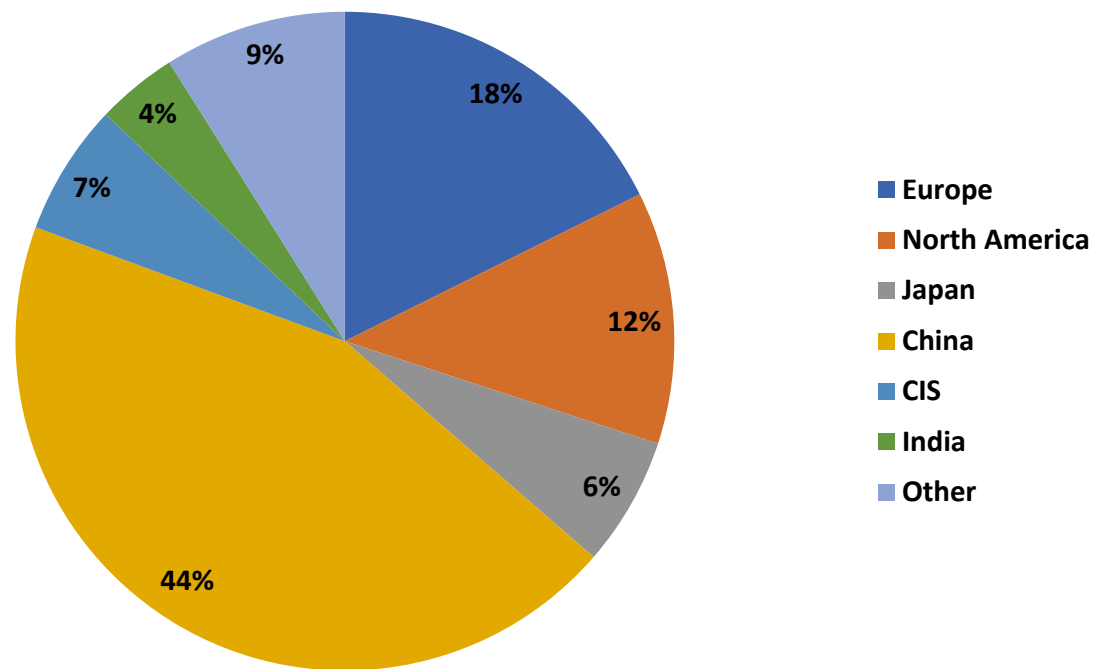


Vanadium Production

Vanadium Production by Country (metric tons V)									% of Total 2018	
	<u>2011</u>	<u>2012</u>	<u>2013</u>	<u>2014</u>	<u>2015</u>	<u>2016</u>	<u>2017</u>	<u>2018e</u>	<u>Global</u>	<u>Ex China</u>
China	40,234	39,630	49,706	53,013	48,562	45,718	47,258	53,635	59%	
Russia	7,725	7,900	8,300	7,807	8,400	7,975	8,300	8,300	9%	22%
South Africa	13,324	13,143	11,971	11,070	10,101	7,954	7,854	8,205	9%	22%
North America	4,163	3,990	4,861	5,763	5,526	3,400	3,000	3,000	3%	8%
Europe	6,650	5,700	6,350	7,000	6,950	8,452	7,785	9,675	11%	25%
Japan	1,000	1,000	1,250	1,500	1,750	1,750	1,950	1,950	2%	5%
Korea	1,200	1,200	1,200	1,200	700	250	250	450	0%	1%
Taiwan	300	300	300	300	400	400	400	300	0%	1%
India	700	700	700	700	700	700	700	700	1%	2%
Australia	-	58	400	100	-	-	-	-	0%	0%
<u>Brazil</u>	-	-	-	500	3,250	4,462	5,433	5,433	6%	14%
Total	75,296	73,621	85,038	88,953	86,339	81,061	82,929	91,647	100%	100%
ex China	35,062	33,991	35,332	35,940	37,777	35,343	35,672	38,013	41%	100%

Vanadium Consumption

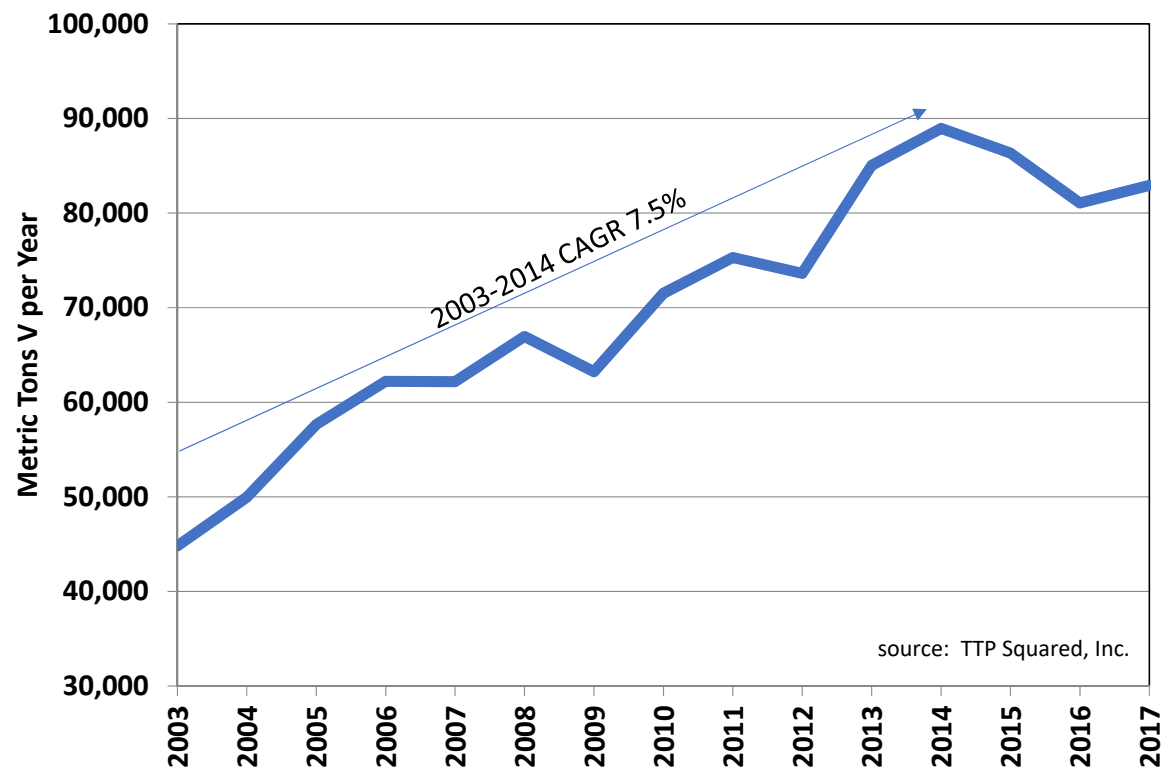
Vanadium Consumption By Region 2017



source: TTP Squared,

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Vanadium Consumption History



source: TTP Squared, Inc.

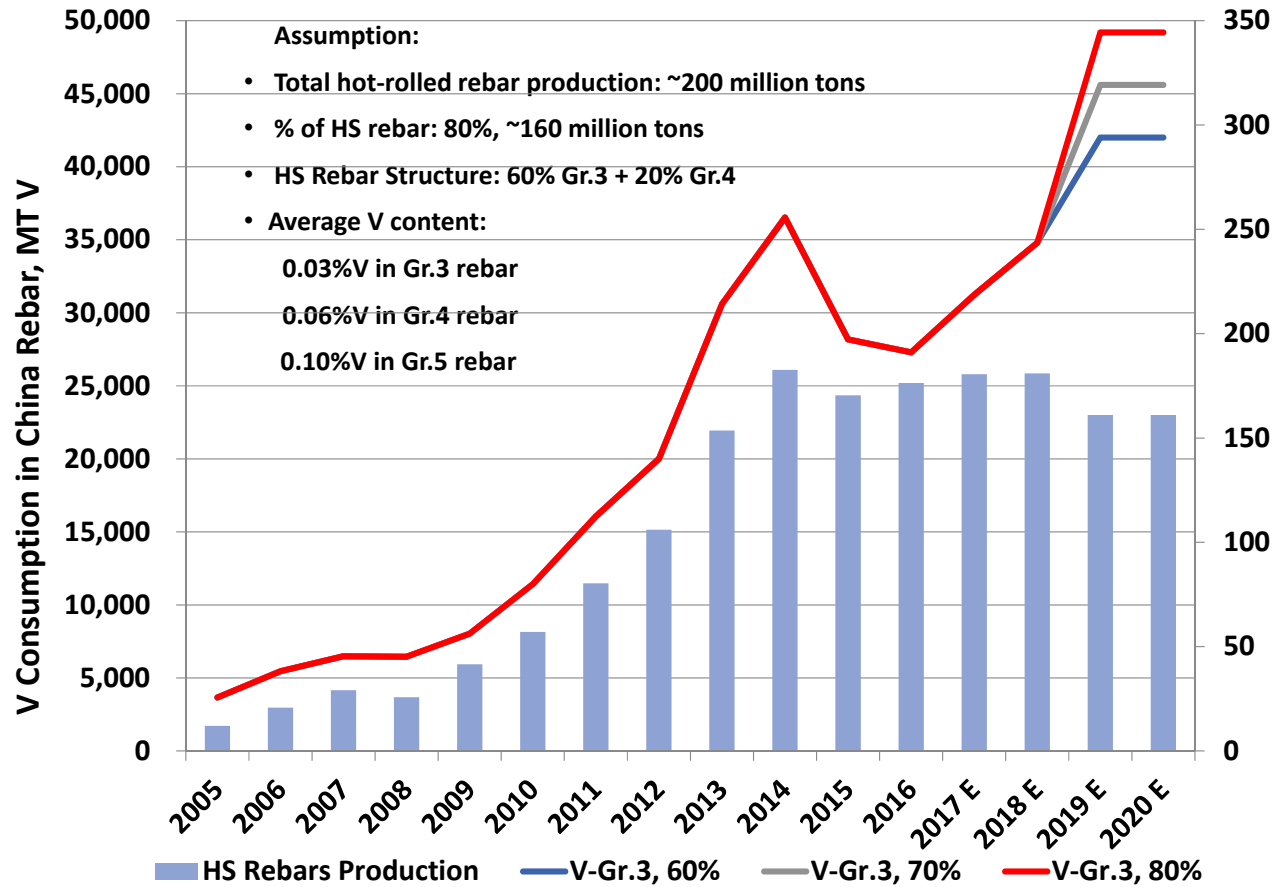
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Vanadium Consumption

Vanadium Consumption by Region (Metric Tons V per Year)									% of Total 2018	
	<u>2011</u>	<u>2012</u>	<u>2013</u>	<u>2014</u>	<u>2015</u>	<u>2016</u>	<u>2017</u>	<u>2018e</u>	<u>Global</u>	<u>Ex China</u>
Europe	16,310	16,213	16,100	16,461	14,988	15,084	15,145	15,448	17%	32%
North America	10,360	10,853	10,815	11,480	10,429	10,573	10,635	10,848	12%	22%
Japan	6,000	6,100	6,415	6,549	5,352	5,297	5,439	5,548	6%	11%
China	25,391	28,578	36,248	44,894	43,865	35,685	37,962	42,981	47%	
CIS	6,370	6,374	6,310	6,308	5,436	5,446	5,546	5,657	6%	12%
India	1,900	2,221	2,586	3,031	3,138	3,249	3,411	3,479	4%	7%
<u>Other</u>	<u>9,481</u>	<u>9,198</u>	<u>8,131</u>	<u>8,011</u>	<u>7,448</u>	<u>6,965</u>	<u>7,679</u>	<u>7,833</u>	9%	16%
Total	75,812	79,536	86,605	96,735	90,655	82,299	85,818	91,794	100%	100%
ex China	50,421	50,958	50,357	51,841	46,790	46,614	47,856	48,813	53%	100%

Vanadium Consumption Chinese Rebar

Source: China Iron & Steel Research Institute (CISRI)



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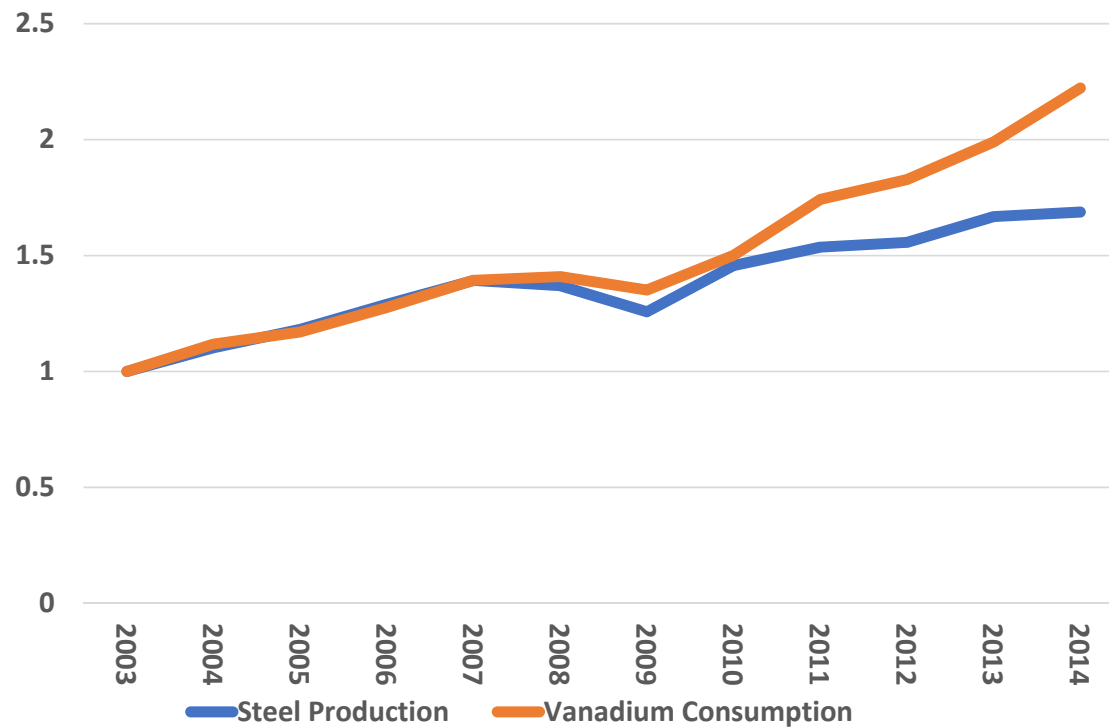
Vanadium Consumption

Demand Drivers

Given the fact that roughly 90% of vanadium consumption today occurs in the steel industry, we can focus on two variables that will be the key drivers to changes in vanadium consumption in the coming years;

- Changes in global steel production rates
- Changes in specific vanadium consumption rates – Kg vanadium consumed per MT steel produced

Vanadium Consumption vs. Steel Production



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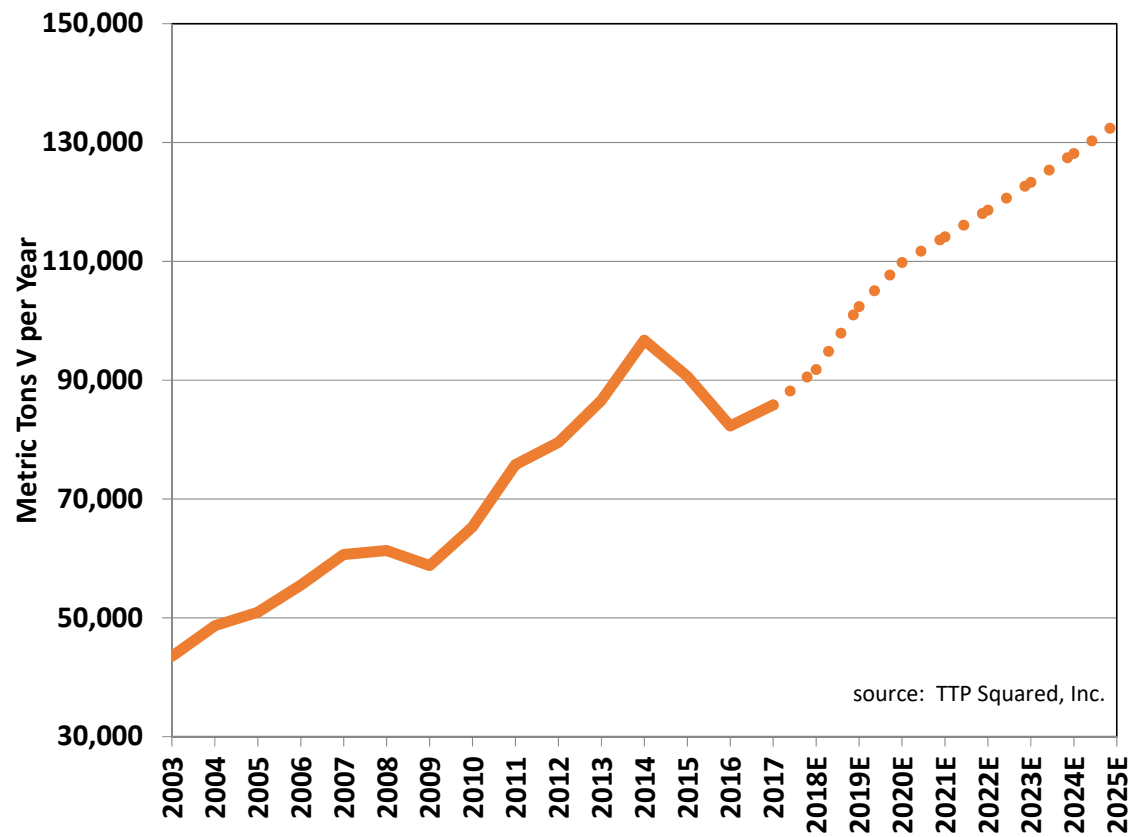
Vanadium Consumption

Forecast Assumptions

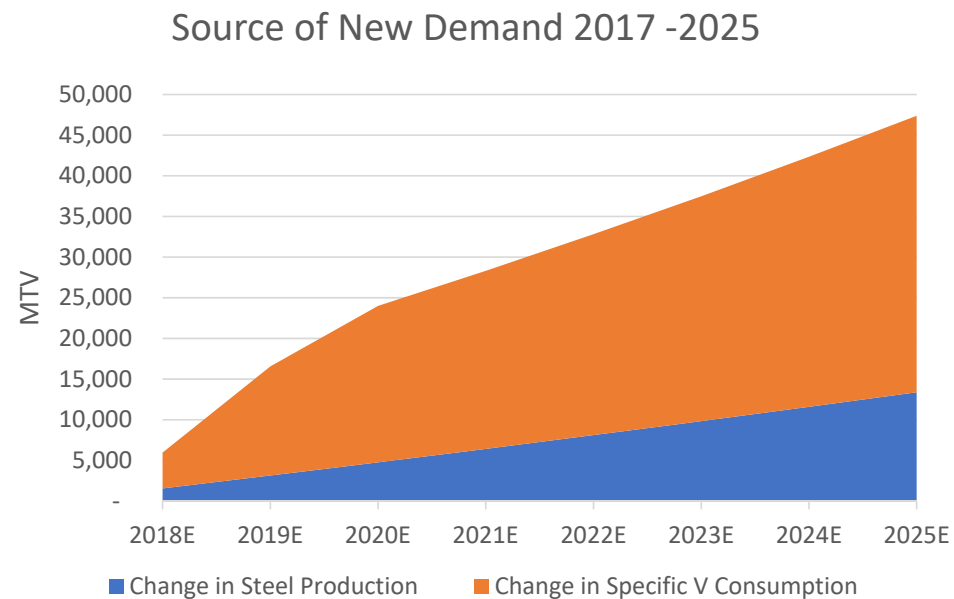
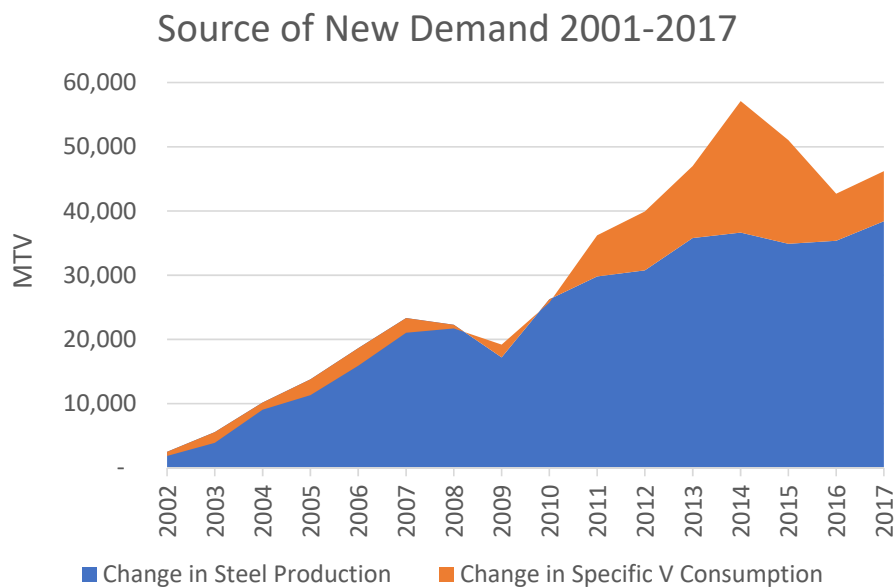
- Surge in new demand 2018-2020 as a result of the revised rebar standard in China
- Specific vanadium consumption growth rate equal to historical levels (1.9% CAGR) post 2020
- Modest growth in global steel production – CAGR 2.5%

Vanadium Consumption

History and Forecast



source: TTP Squared, Inc.

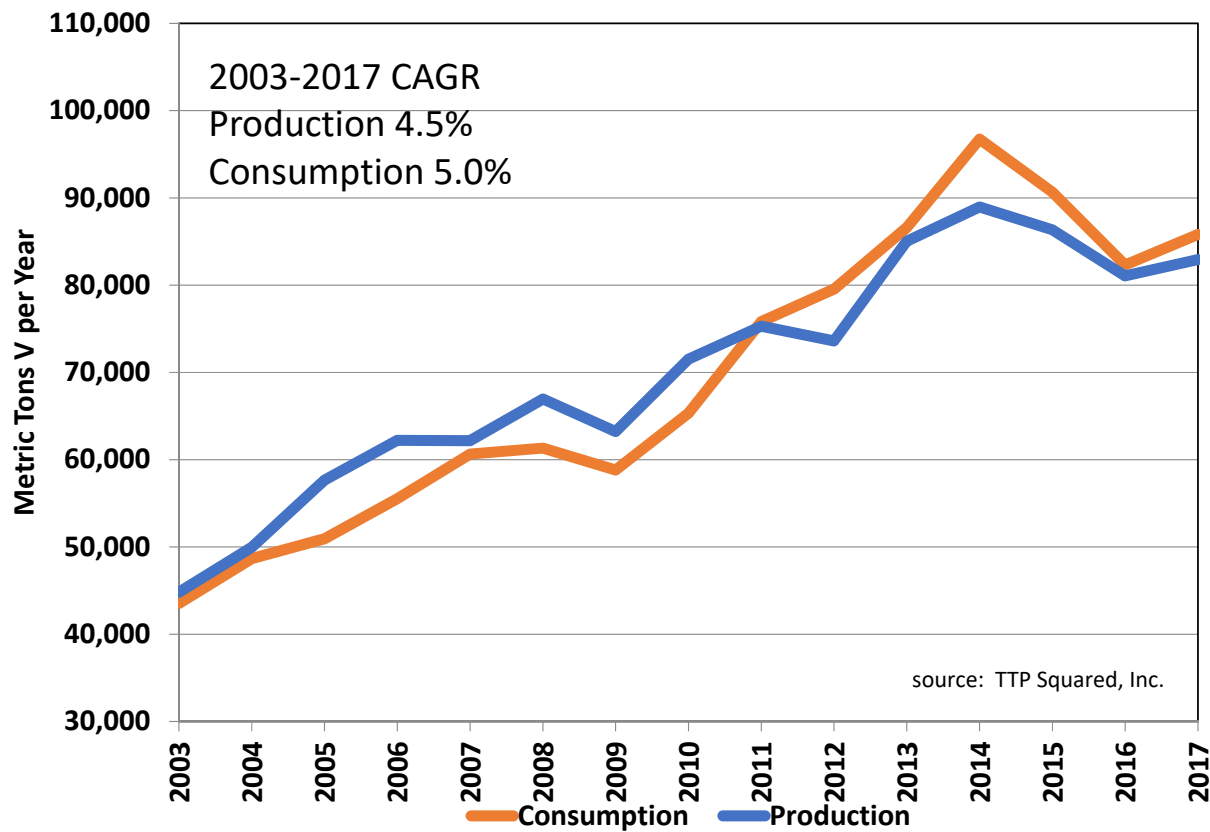


Growth in Vanadium Consumption in the past has been primarily driven by growth in global steel production volumes. Looking forward the majority of growth in vanadium consumption will be driven by increasing specific vanadium consumption rates rather than by growth from steel production as the world steel industry continues to mature and growth rates decrease while product quality increases

Vanadium Inventory

Vanadium Inventory

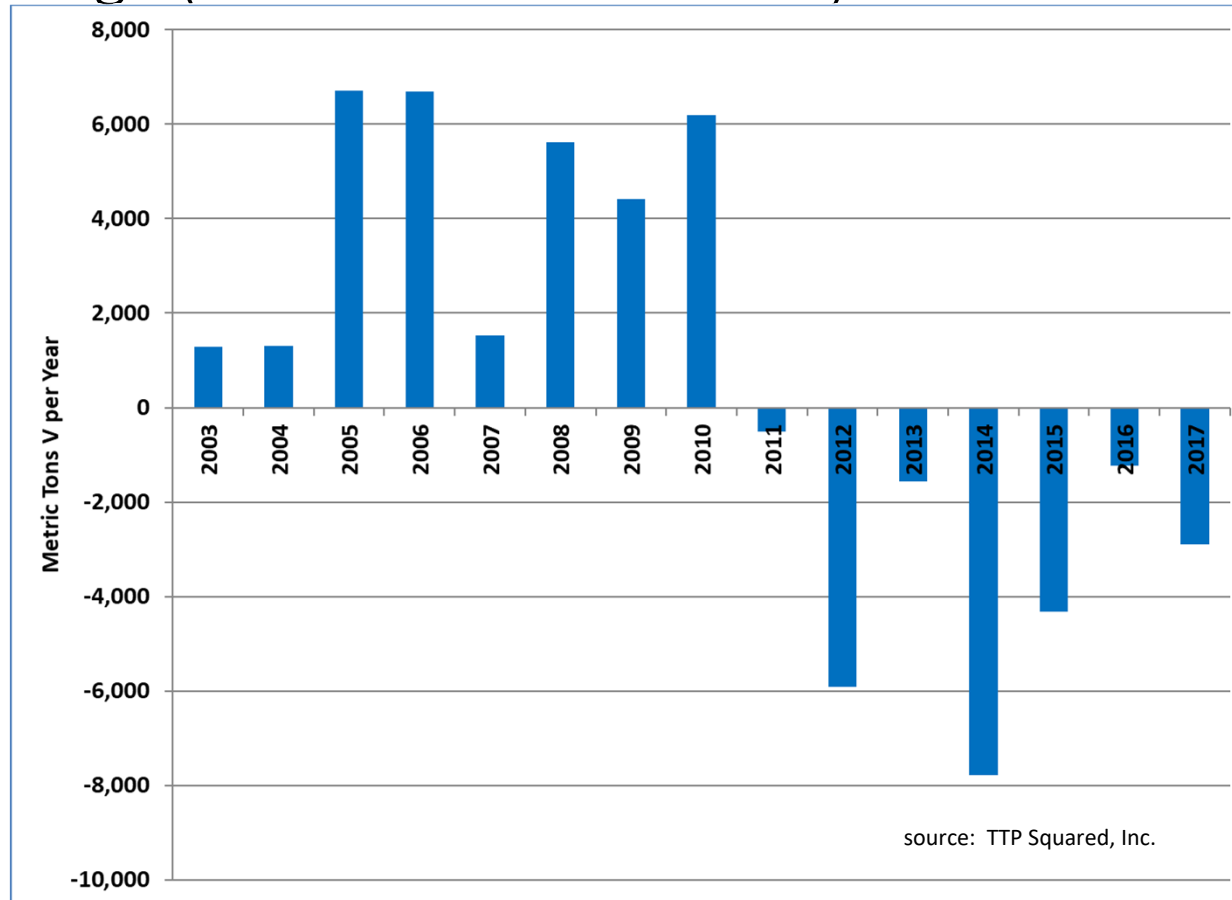
Production and Consumption History



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Vanadium Inventory

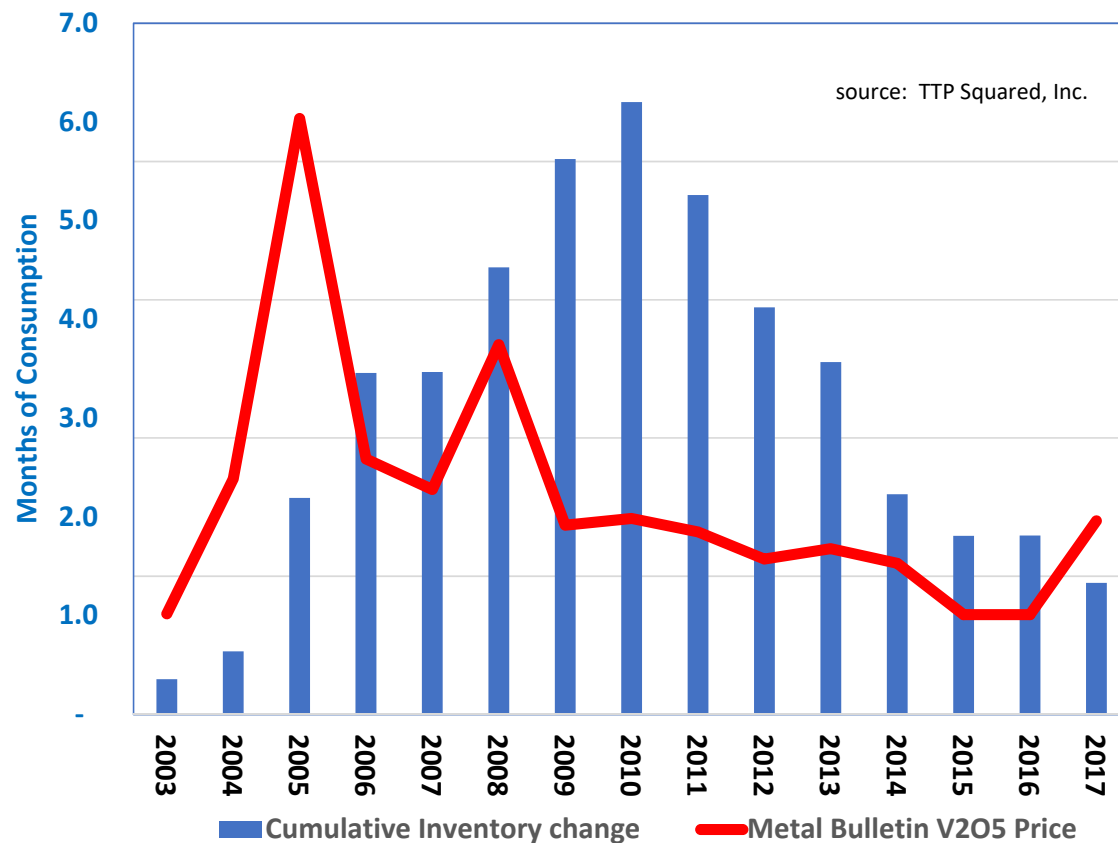
Annual Change (Metric Tons Vanadium)



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Vanadium Inventory

Cumulative Change (Metric Tons Vanadium)

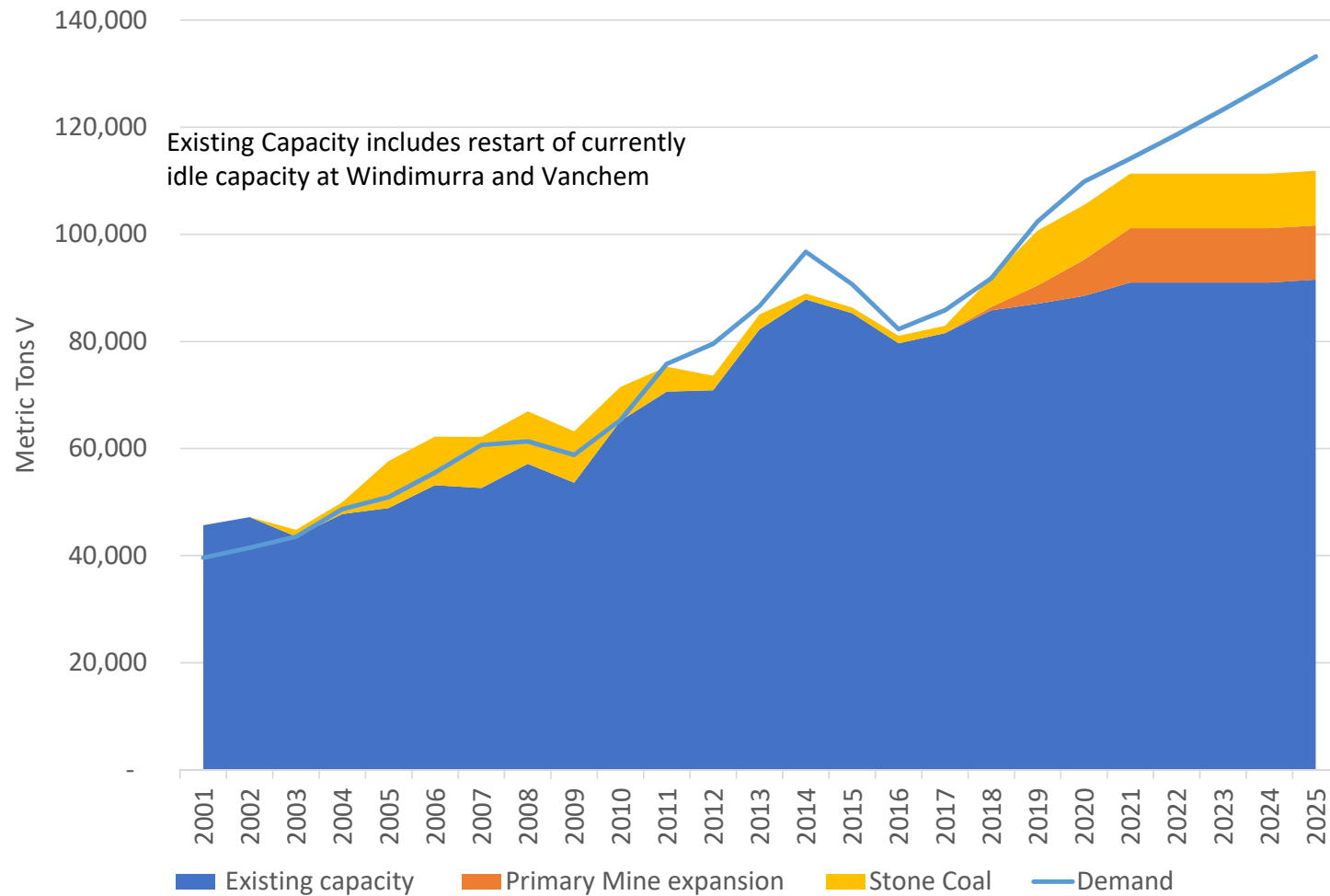


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Forecast Assumptions

- Restart of all idle capacity on a global basis by 2021
 - Windimurra – Western Australia
 - Vanchem – South Africa
 - Stone Coal mines – China
- Significant Expansions at existing primary vanadium mines
 - Largo Resources - Brazil
 - Glencore Rhovan – South Africa
 - Bushveld Minerals – South Africa
- Increase in recovery of vanadium from secondary sources
- No new primary sources of vanadium

Vanadium Supply and Demand

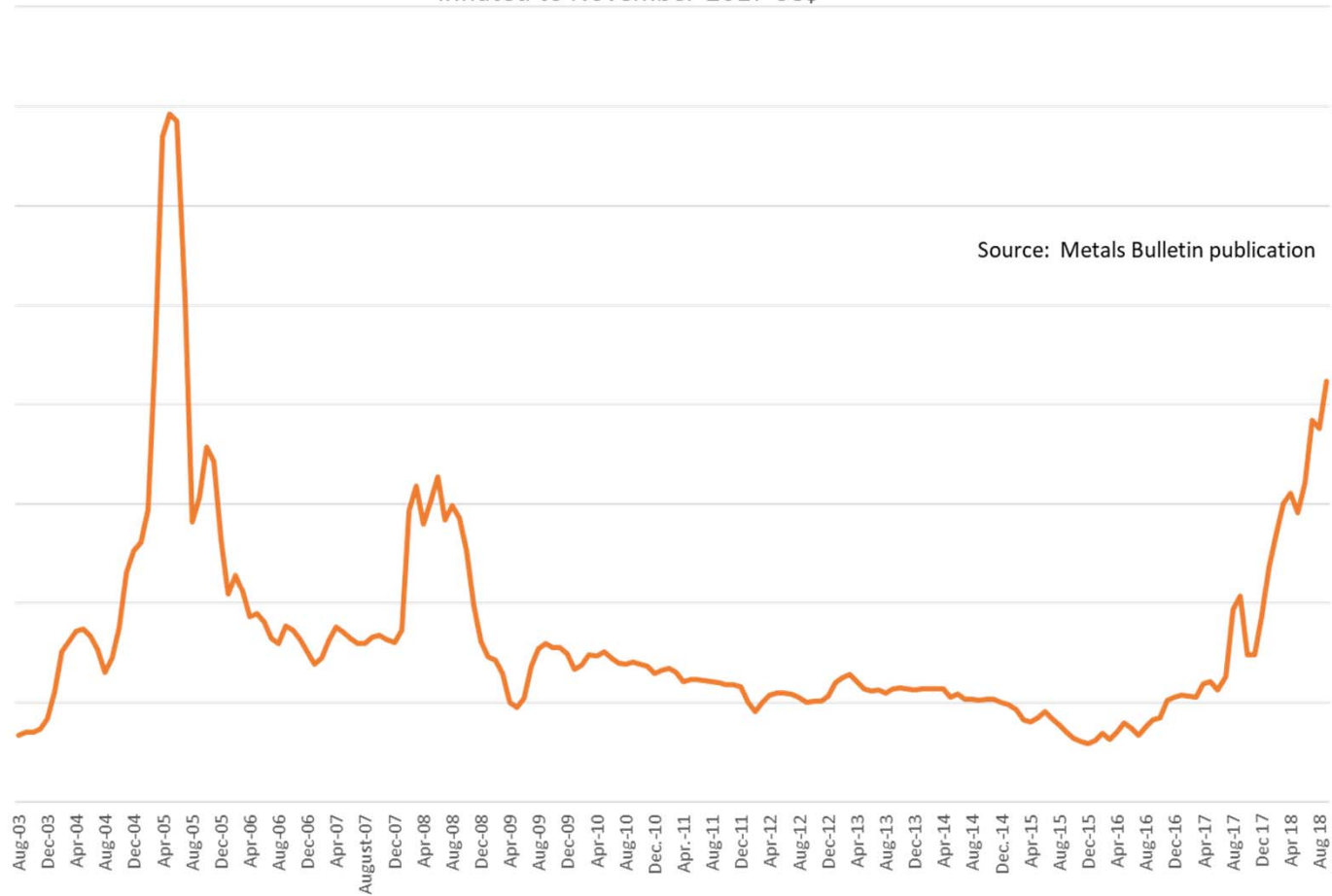


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Vanadium Summary

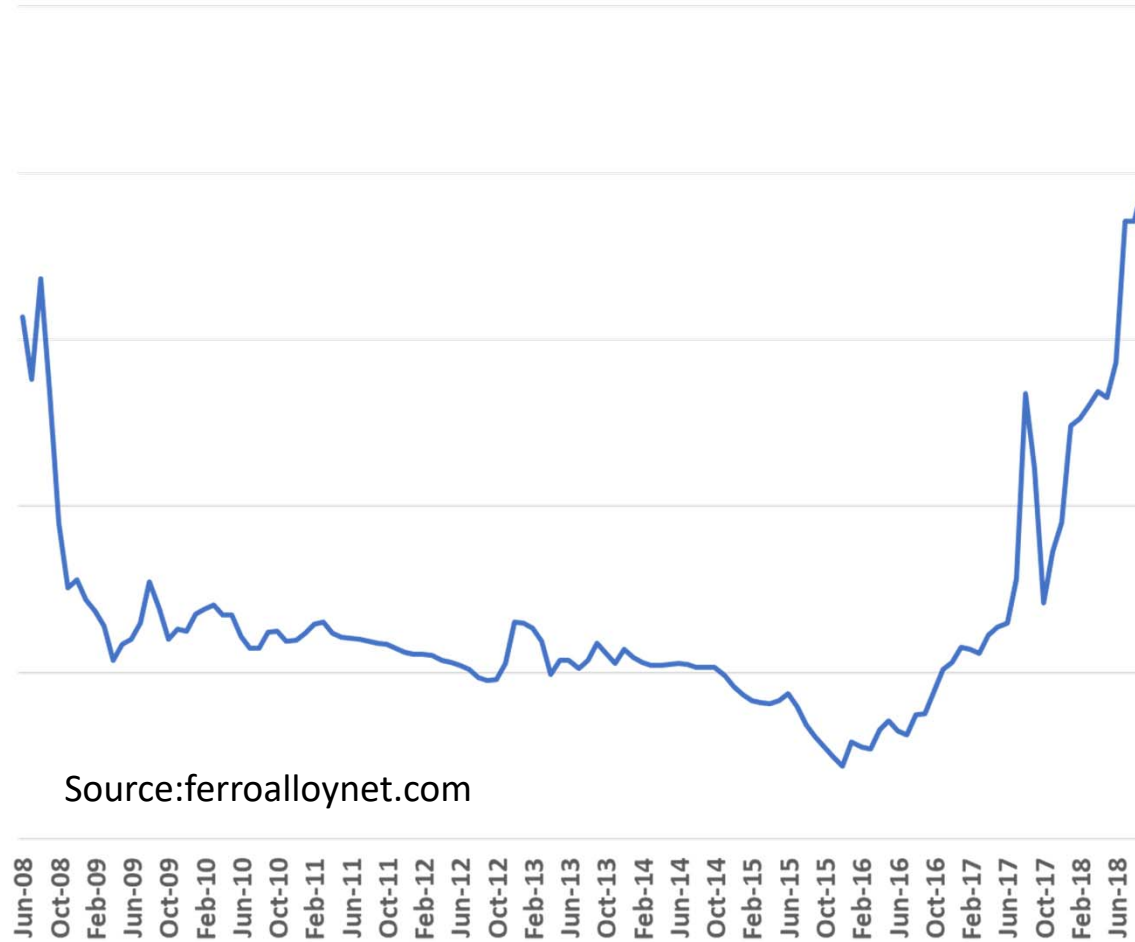
- Historically high prices in 2005 combined with exploding steel production in China from 2004-2010 lead to massive increases in vanadium supply, primarily from Chinese steel mills utilizing vanadium bearing ores.
- Historically weak vanadium prices in 2014-2016 lead to significant reduction in supply with some past sources being liquidated and thus unable to restart under any condition.
- Excess inventories built from 2005-2010 kept downward pressure on the market even after the major closures of 2014-2015.
- Today it appears excess inventory is depleted and the supply base will struggle to meet demand in the next few years.
- Clearly there is a need for new sources of vanadium to meet the growing market demand, particularly from 2022 onward.
- This analysis does not assume any increase in vanadium consumption from energy storage applications (batteries) which may be erroneous

Metal Bulletin V2O5 Monthly Midpoint Average Price
 Sept. 2003- August 2018
 Inflated to November 2017 US\$



Source: Metals Bulletin publication

China V2O5 Monthly Price



Source:ferroalloynet.com

China V2O5 Daily Price



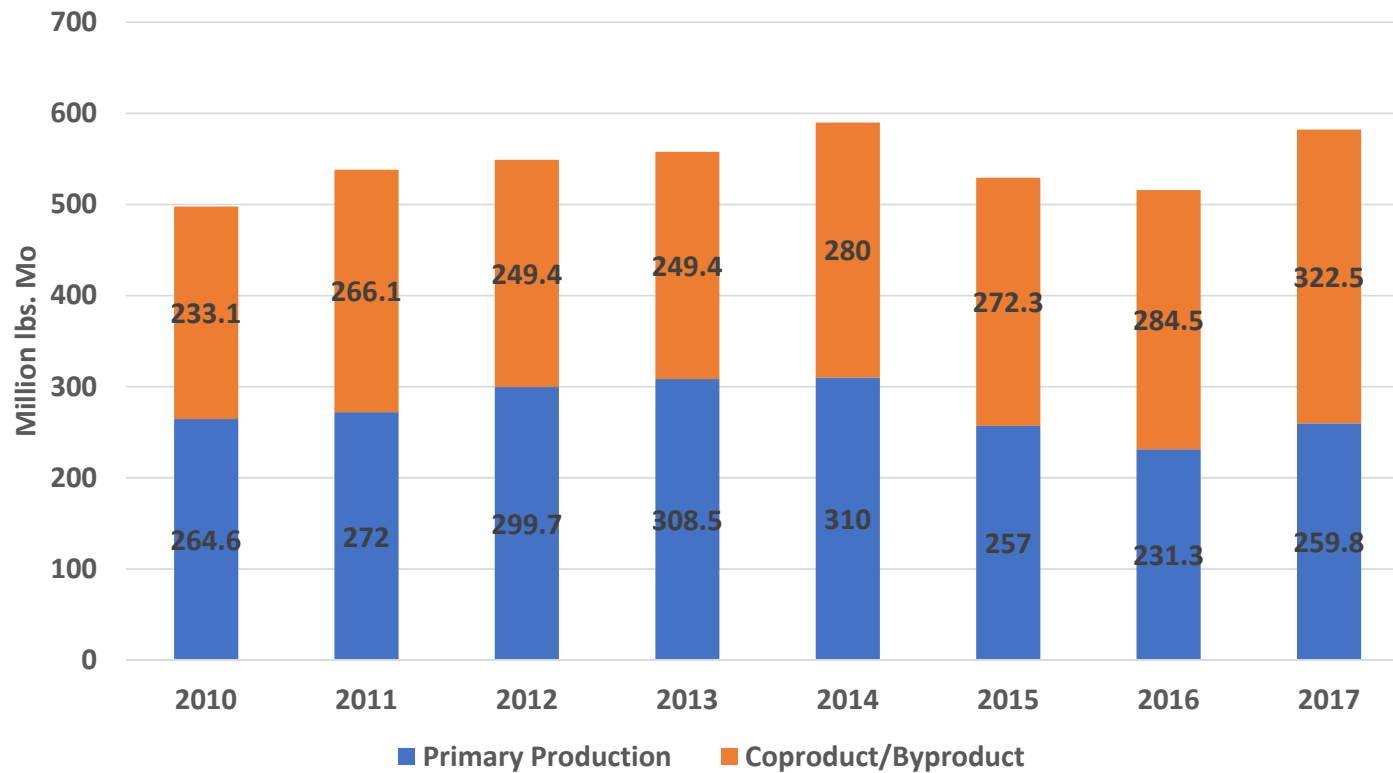
Source:ferroalloy.net.com

12-Dec-16
12-Jan-17
12-Feb-17
12-Mar-17
12-Apr-17
12-May-17
12-Jun-17
12-Jul-17
12-Aug-17
12-Sep-17
12-Oct-17
12-Nov-17
12-Dec-17
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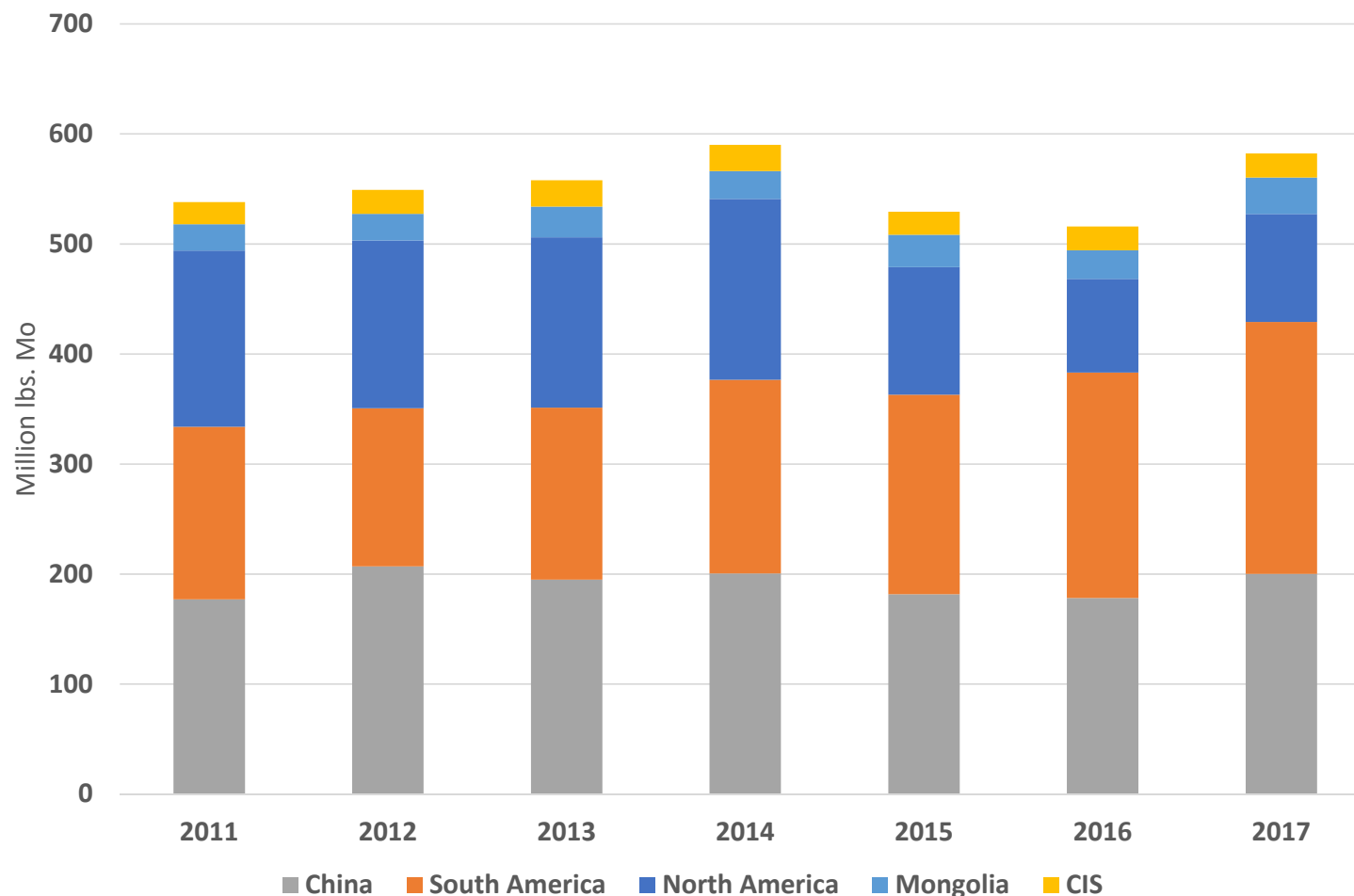
Molybdenum

Molybdenum Production by Source



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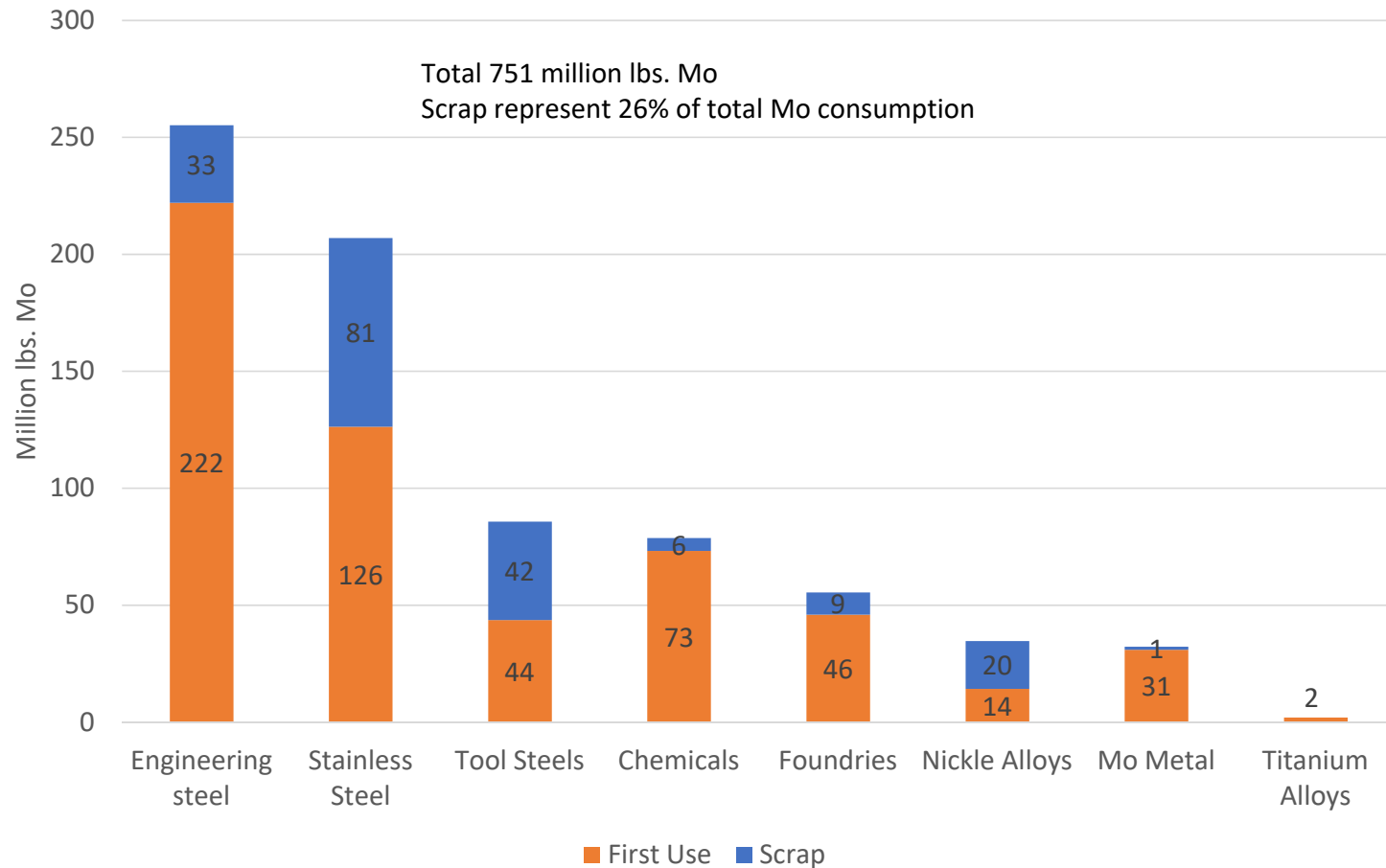
Mo Production by Region



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Molybdenum Consumption

Mo Consumption 2017 Including Scrap

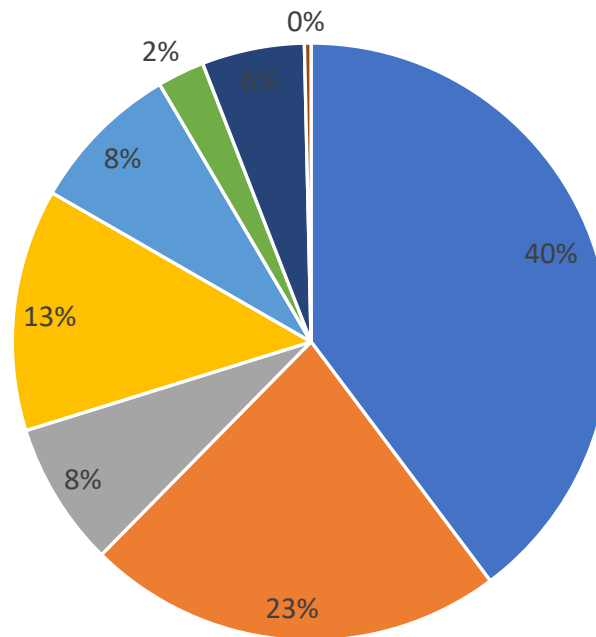


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Molybdenum First Use by Application

2017

558 million pounds Mo

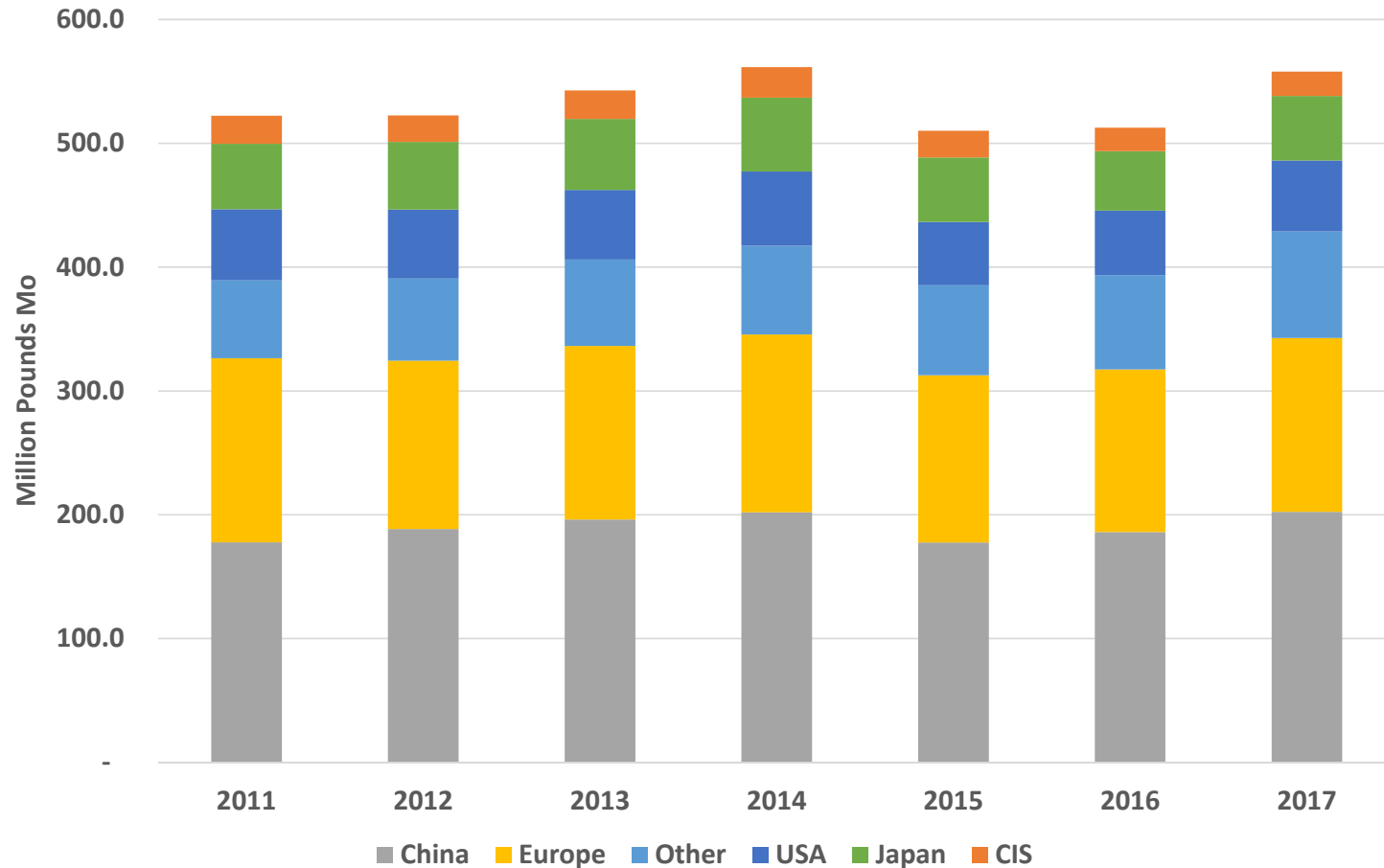


- Engineering steel
- Stainless Steel
- Tool Steels
- Chemicals
- Foundries
- Nickle Alloys
- Mo Metal
- Titanium Alloys

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Mo Consumption by Region

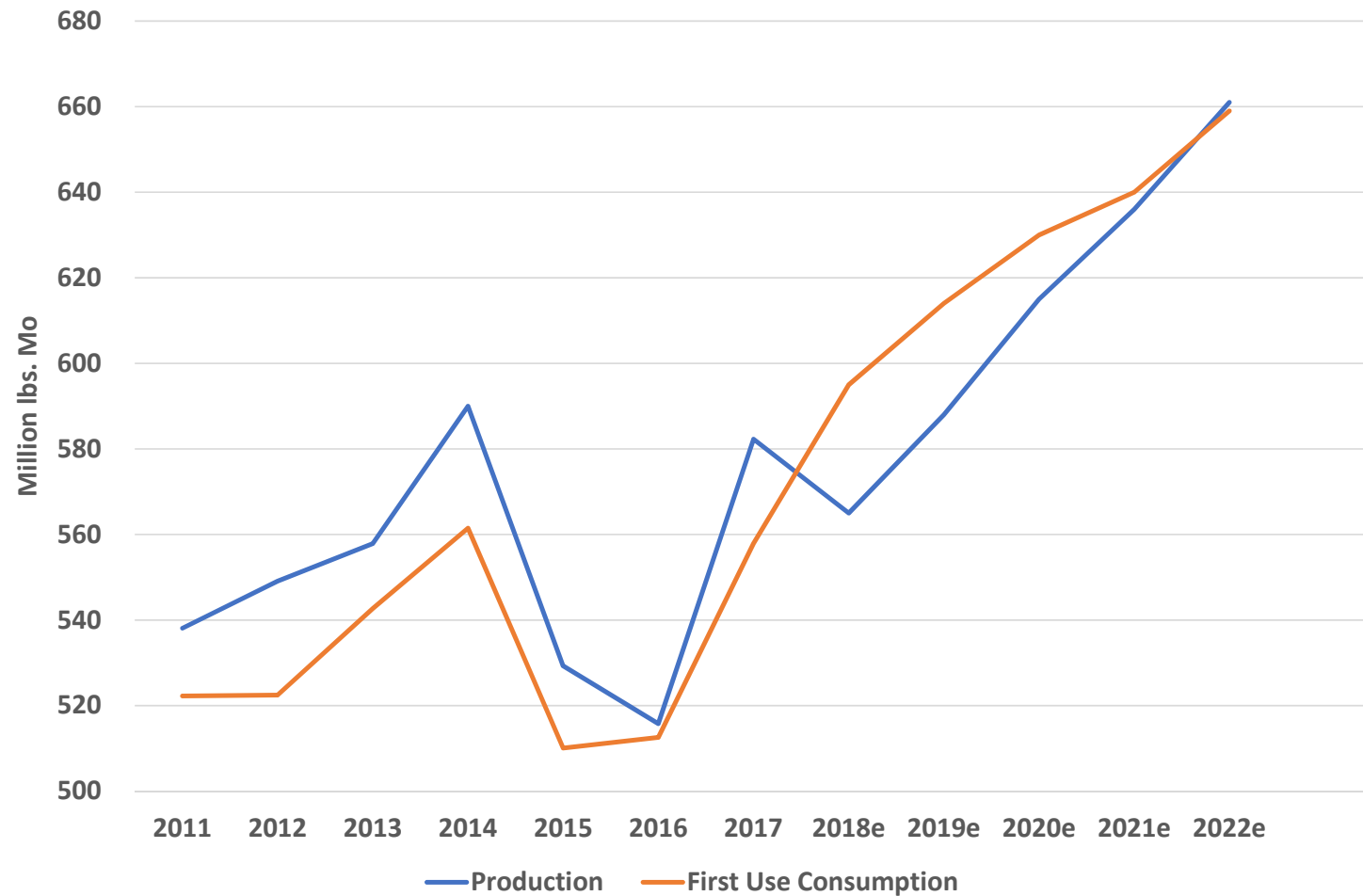
First Use



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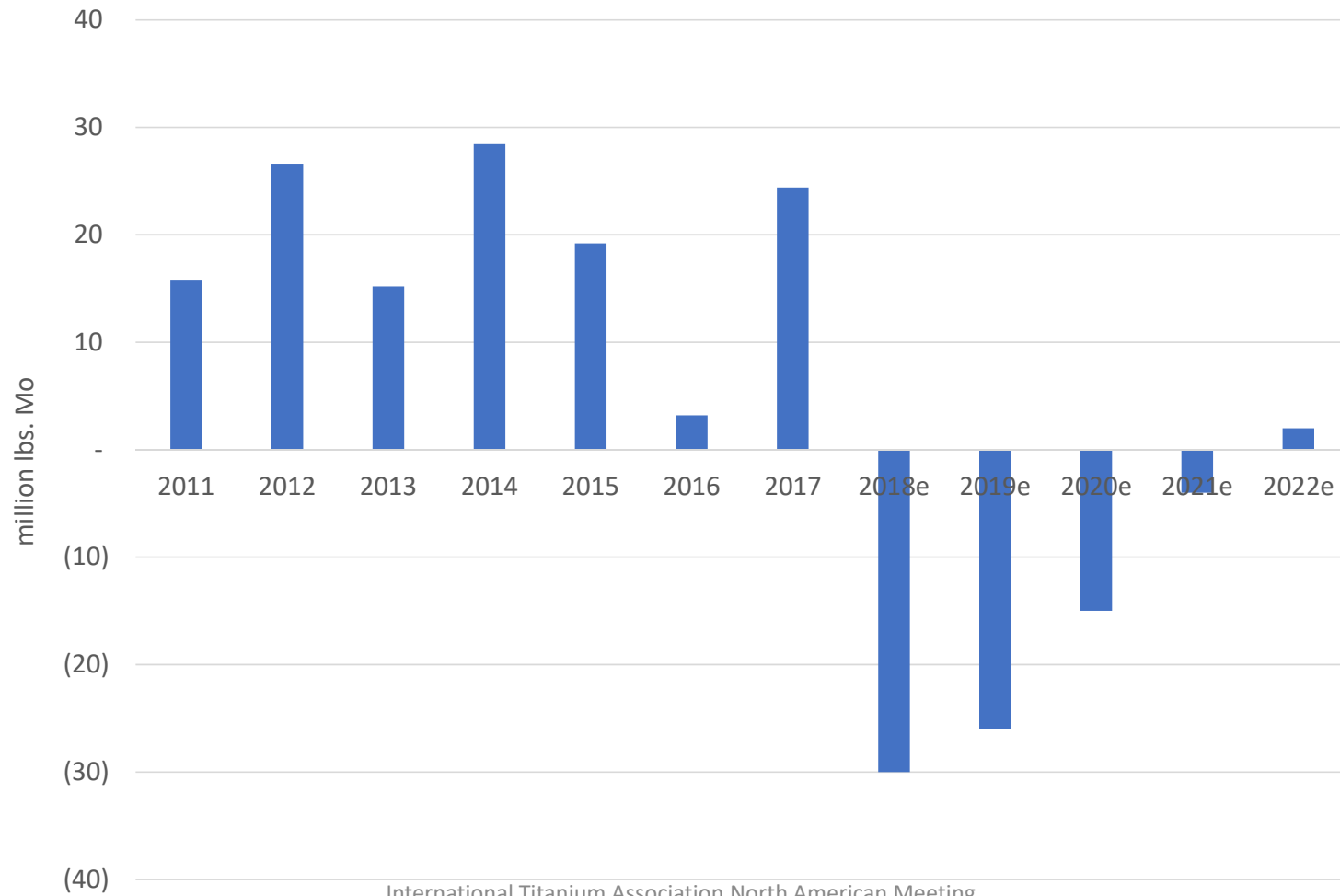
Molybdenum Inventory

Mo Production and Consumption

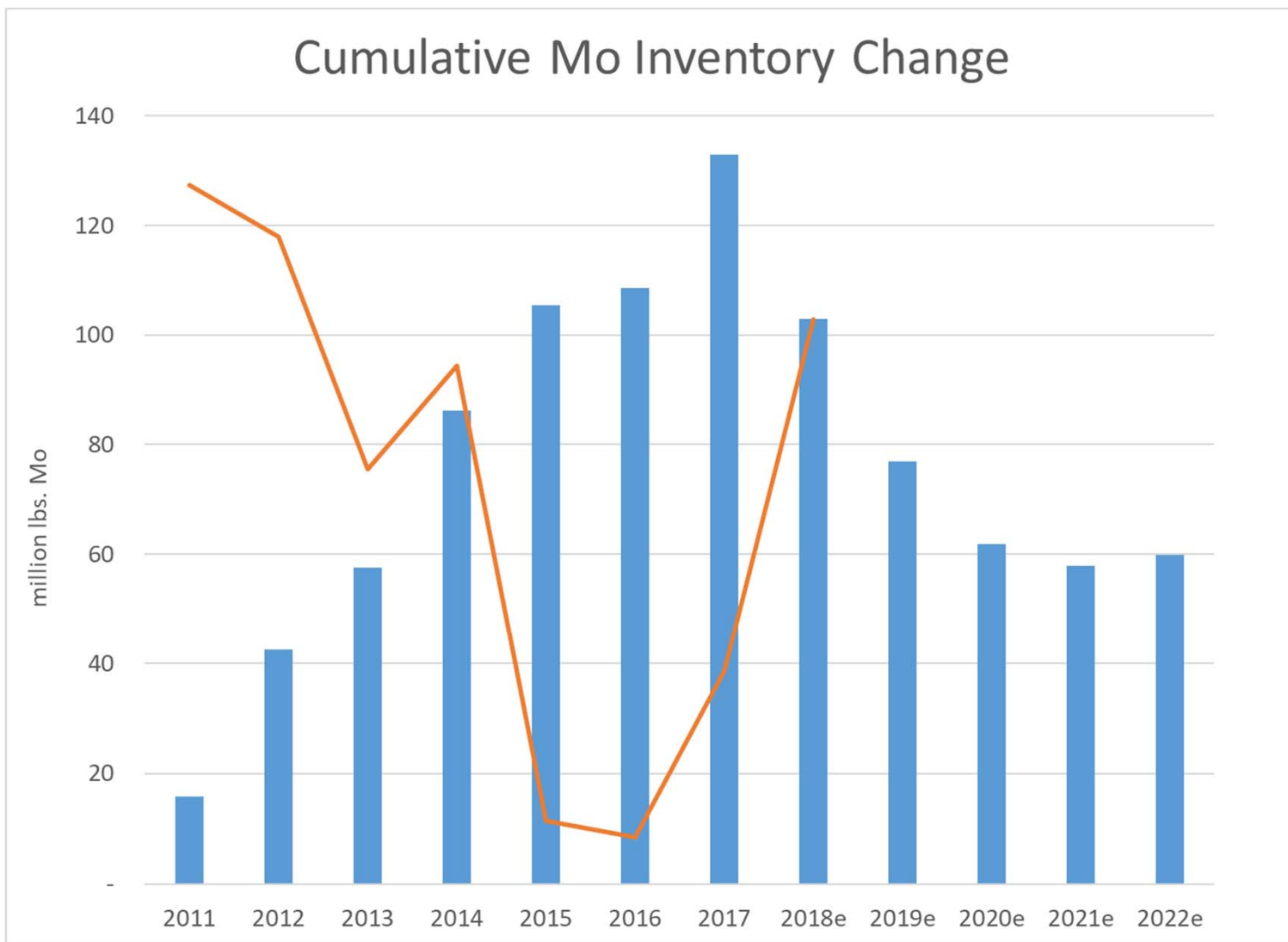


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Annual Mo Inventory Change



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Molybdenum Summary

- Global market was in severe over-supply following demand collapse in 2015.
- 2015 saw large demand and supply falls, but still a surplus market.
- 2016 and 2017 a tighter market following 2015/16 supply cuts then strong demand recovery in 2017.
- First half-2018 very strong demand
- Oil and gas investment collapse in 2015/16 –now recovery
- Following consumption decline in 2015/16, strong bounce-back in 2017/18 followed by reversion to trend or even weaker in 2019/20?
- China potential to surprise on upside given its low per capita use in 316 stainless (there was surprising stainless strength in 2017, especially in 300 series)
- Large supply shortfalls projected in 2018/19, which will have to be met by destocking.

Master Alloys

- Master Alloys in the titanium industry are binary, ternary or multi-component alloys used to efficiently and effectively allow the melting of titanium alloys.
- Vanadium and molybdenum master alloys account for approximately 90% of the total annual demand volume
- More than 40 master alloys are regularly used by the titanium industry including master alloys of Co, Cu, Cr, Nb, Ni, Si, Sn and Zr

Master Alloys

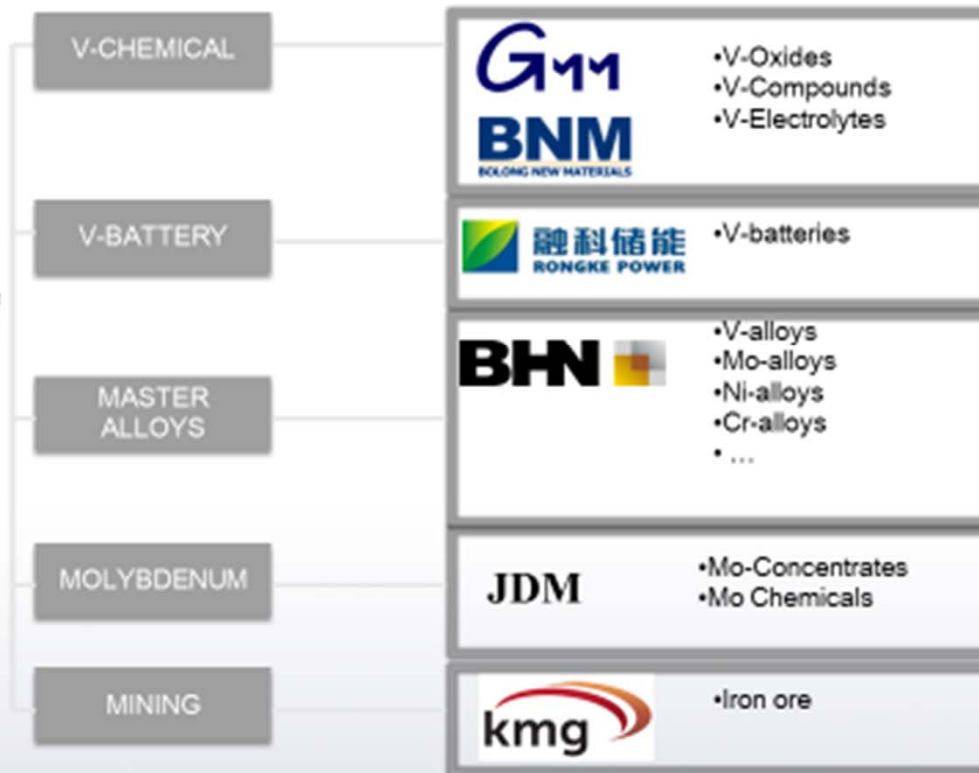
- Quality is an absolutely critical attribute for master alloys given their use in critical applications.
- A critical and highly variable cost component in master alloy production is the market price of raw materials – primarily V and Mo
- Assurance of supply of the broad range of master alloys necessary is an important issue.
- The ability of the master alloy supplier to design solutions for titanium alloy producers is a critical value added factor in the relationship.

Master Alloys

- Master Alloy producers can create value for the titanium alloy producers by bringing several capabilities to the table:
 - All necessary quality certifications
 - Upstream supply of V and Mo to provide competitive prices and minimize market risk
 - The experience and ability to bring metallurgical solutions to the table to improve existing alloy production methods and develop alloy systems for new titanium alloys.

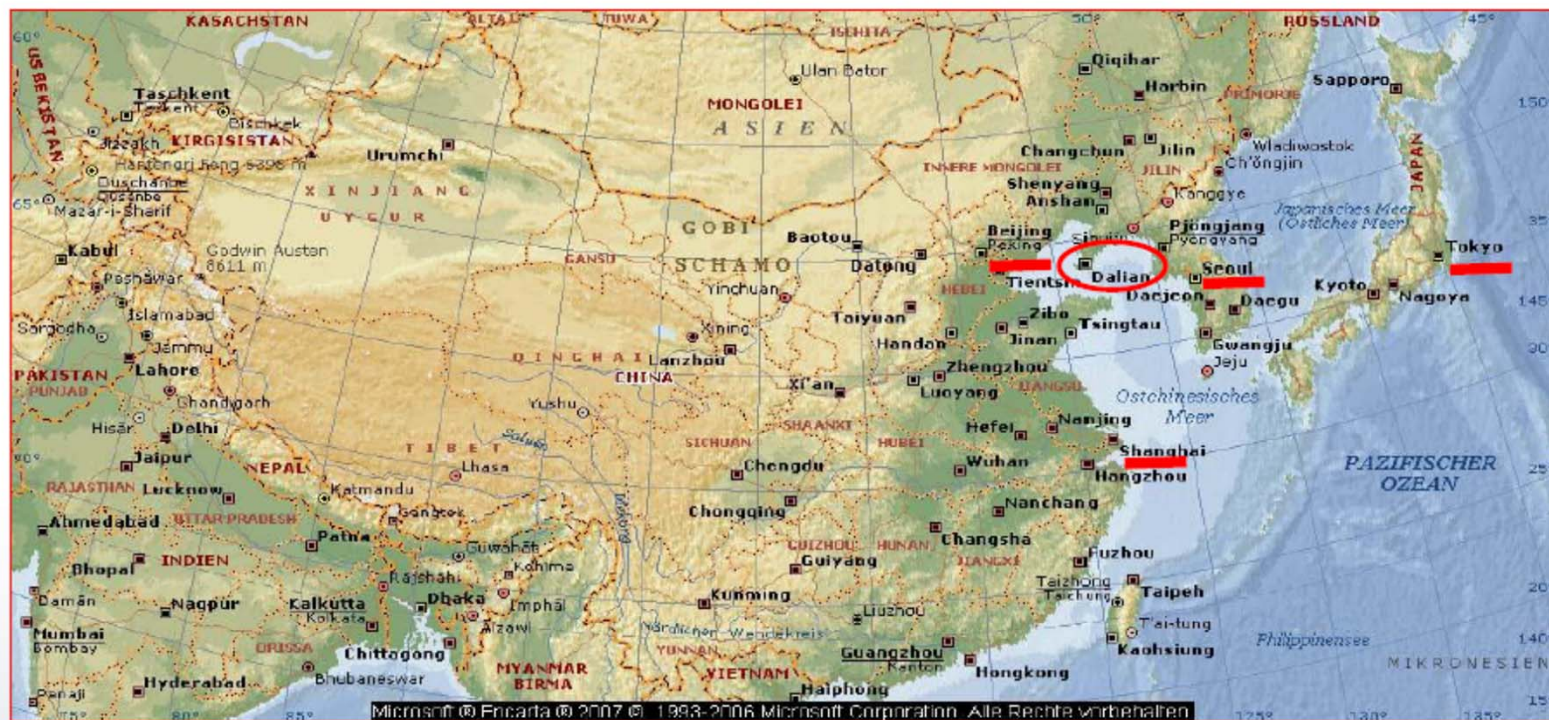
BHN Special Materials Ltd.

BOLONG Group-Main Business



Business Sensitive

Where are we? – HYK, Huayuankou Economic Zone,
Dalian, Liaoning Province, PR China



How well we do it: Management

Certification		since
EN 9100:2009	Aerospace Quality Management System	Oct. 2010
ISO 9001:2008	Quality Management System	Nov. 2011



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Comparison of Melting Temperatures and Densities



VAR, standard raw material input for Ti 10-2-3 , Ti-10V-2Fe-3Al:

Material	Raw material input ratio (wt%)	Melting temperature (°C)	Density (kg / dm ³)	Remark
VAI 85:15	12.47	1,890	5.14	standard raw material input
Titanium metal	85.26	1,668	4.51	standard raw material input
Iron metal	1.81	1,538	7.87	standard raw material input
Aluminum metal	0.79	660	2.70	standard raw material input

max	1,890	7.87
weight average	1,685	4.63
min	660	2.70

STDEV	539	2.14
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Δ min-max	1,230	5.17
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Comparison of Melting Temperatures and Densities



VAR, sophisticated raw material input for Ti 10-2-3, Ti-10V-2Fe-3Al :

Material	Raw material input ratio (wt%)	Melting temperature (°C)	Density (kg / dm ³)	Remark
VAIFe 69:19:12	15.00	1,730	5.03	sophisticated raw material input
Titanium metal	85.26	1,668	4.51	standard raw material input

max	1,730	5.03
weight average	1,677	4.59
min	1,668	4.51

STDEV	44	0.37
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Δ min-max	62	0.52
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Advantages of VAlFe 69:19:12



- ✓ The standard recipe for Ti 10-2-3 has a delta in melting temperature of 1,230°C and a delta in density of 5.17 kg / dm³ for the raw material input
- ✓ The characteristics of VAlFe 69:19:12 is closer to denominator Titanium metal by temperature, density and morphology
- ✓ The parameters of BHN's ternary master alloy improve:
 - the handling of the pressed electrode [for VAR consolidation melt]
 - the melting and dissolution activity of alloying components in the Titanium matrix
 - homogeneity of the 1st VAR ingot [consolidation melt], minimize VAR defects, and may even result in saving 1 VAR melting step for industrial application

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Where to go with Titanium Master Alloys ?



➤ The perfect Master Alloy for Titanium Alloys

- ◆ pseudo binary alloy, ***theoretical*** approach: Ti-V, Ti-Mo, Ti-Nb, Ti-etc.
 - * highly flexible but expensive
 - in volume utilizing the same or similar, expensive equipment, e.g. VAR, VIM, EB
 - * technically tough to make
 - in quality [homogeneity, contamination-free and size]
- ◆ binary alloy, ***pragmatic*** approach: Al-V, Al-Mo, Al-Nb, Al-etc.
 - * but not all oxides can be reduced by ATR – see Mr. Ellingham
 - * but not all compositions can satisfy every defined final Ti-Al alloy
- ◆ BHN master alloys, ***the solution***
 - * just kindly provide your RFQ and BHN will advise the best option

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Thanks!