Vanadium Market Analysis

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TTP Squared, Inc.

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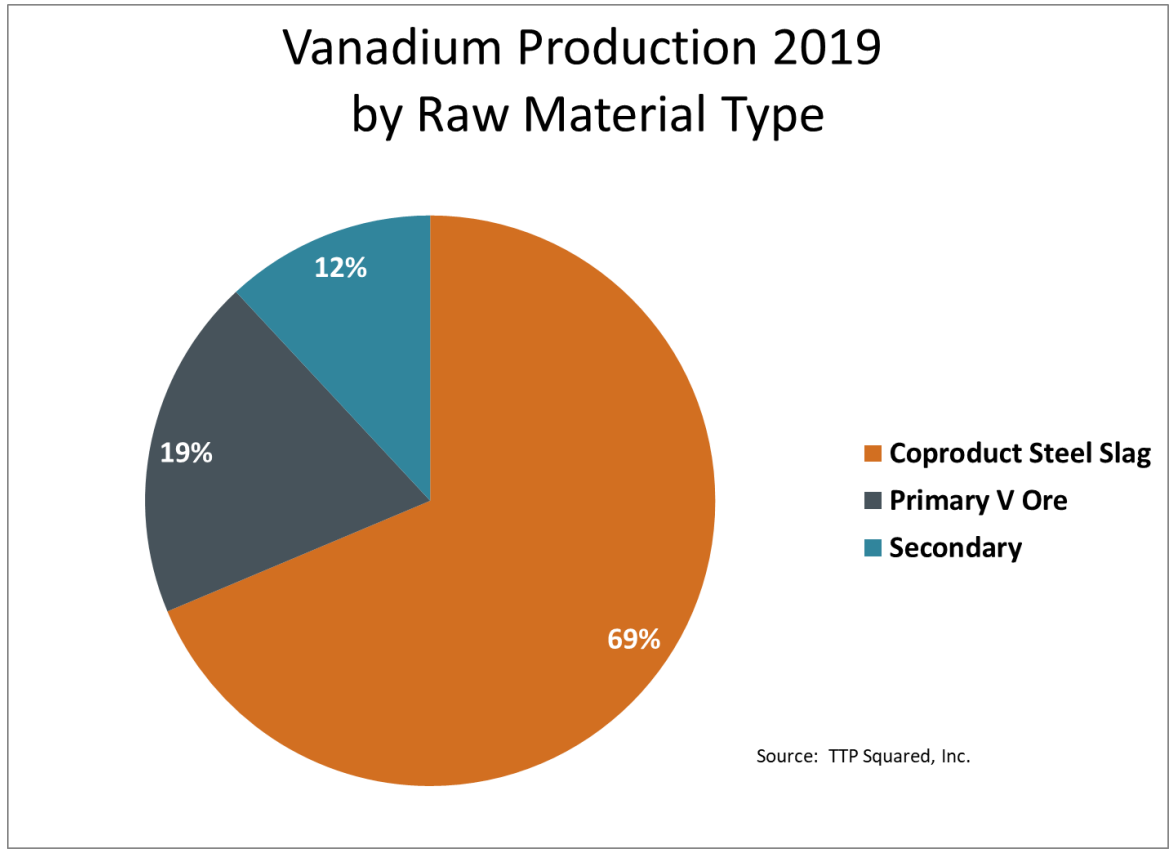
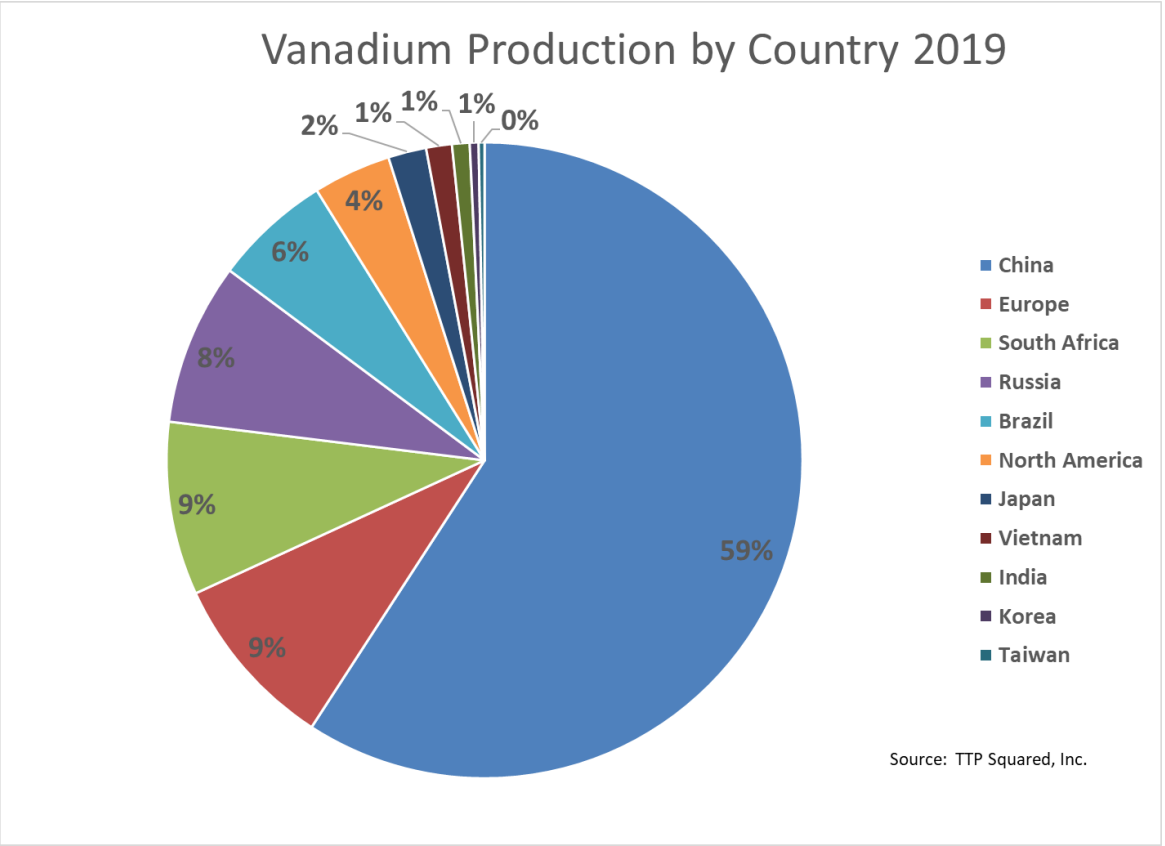
2020 Projections from TTP Squared, Inc.

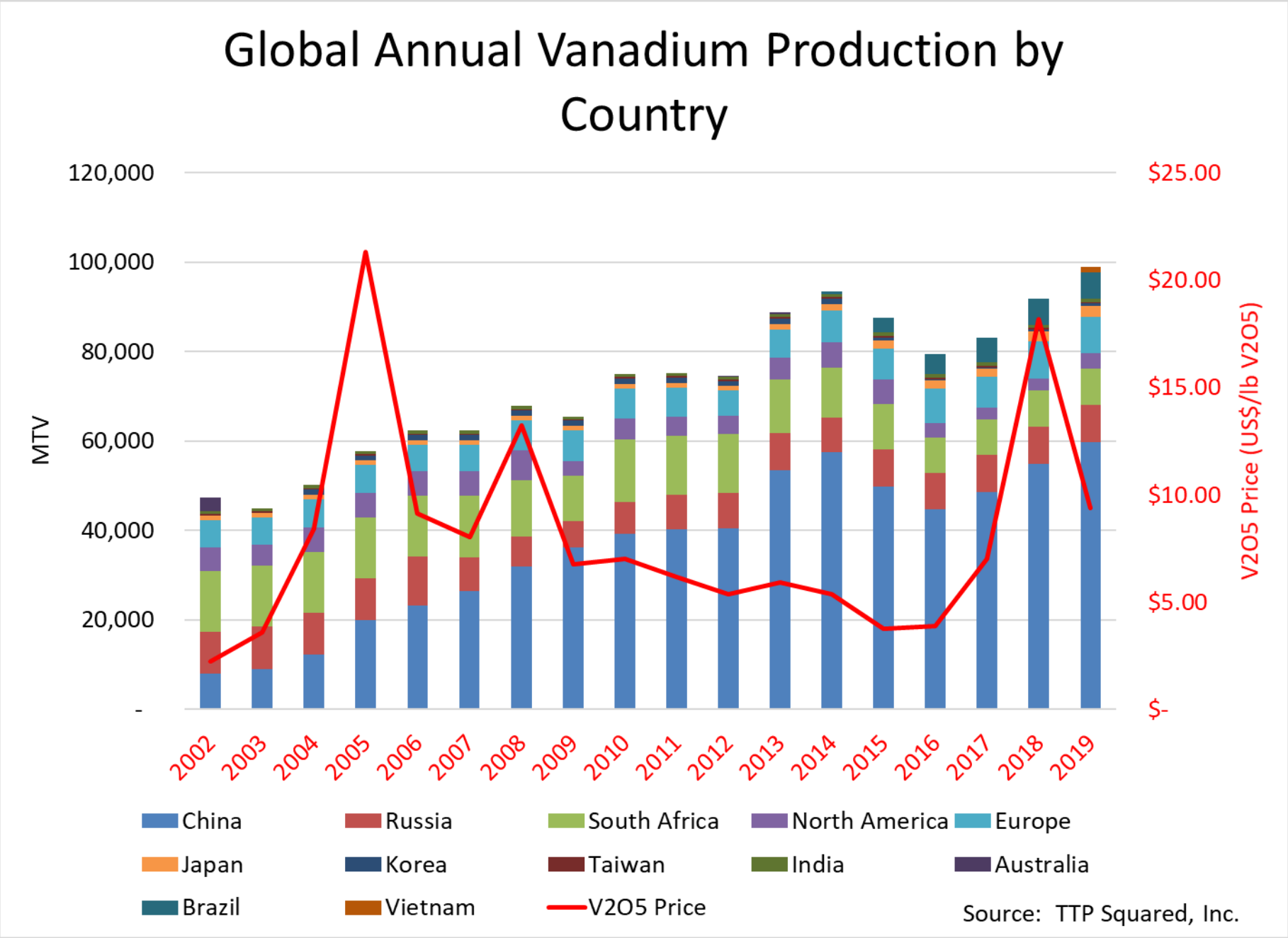
- Ex China in 2020 we expect:
  - Ex China vanadium consumption will increase slightly to 52,800 MTV.
  - Ex China vanadium production will increase slightly to 42,500 MTV.
  - This suggests a deficit ex China in 2020 of 10,300 MTV.

- Mainland China in 2020 we expect:
  - Total rebar production in China to be similar to 2019 production levels.
  - China vanadium consumption will continue a significant increase in vanadium consumption as quench and temper rebar is replaced with alloyed rebar.
  - We project vanadium consumption in China in 2020 at 60,100 MTV.
  - We expect Chinese vanadium production in 2020 to total 63,900 MTV.
    - Some of the new Chinese production which began to appear in late 2018 during the price spike has very high costs.
    - Market prices will have to rise to justify the continuation of these new sources of production.
- The analysis suggests that there will not be adequate Chinese exports available to keep western markets in balance in 2020
- We expect market prices must rise to justify continuation of the high cost sources of production so as to meet the growth in consumption projected for 2020.

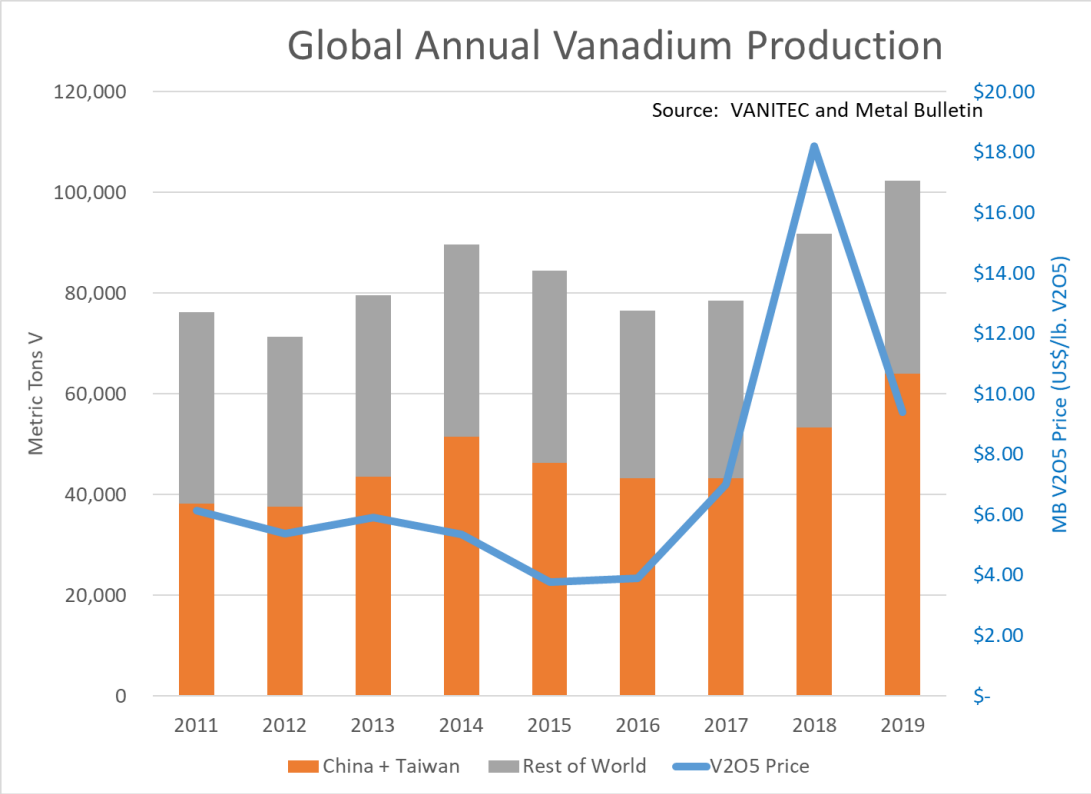


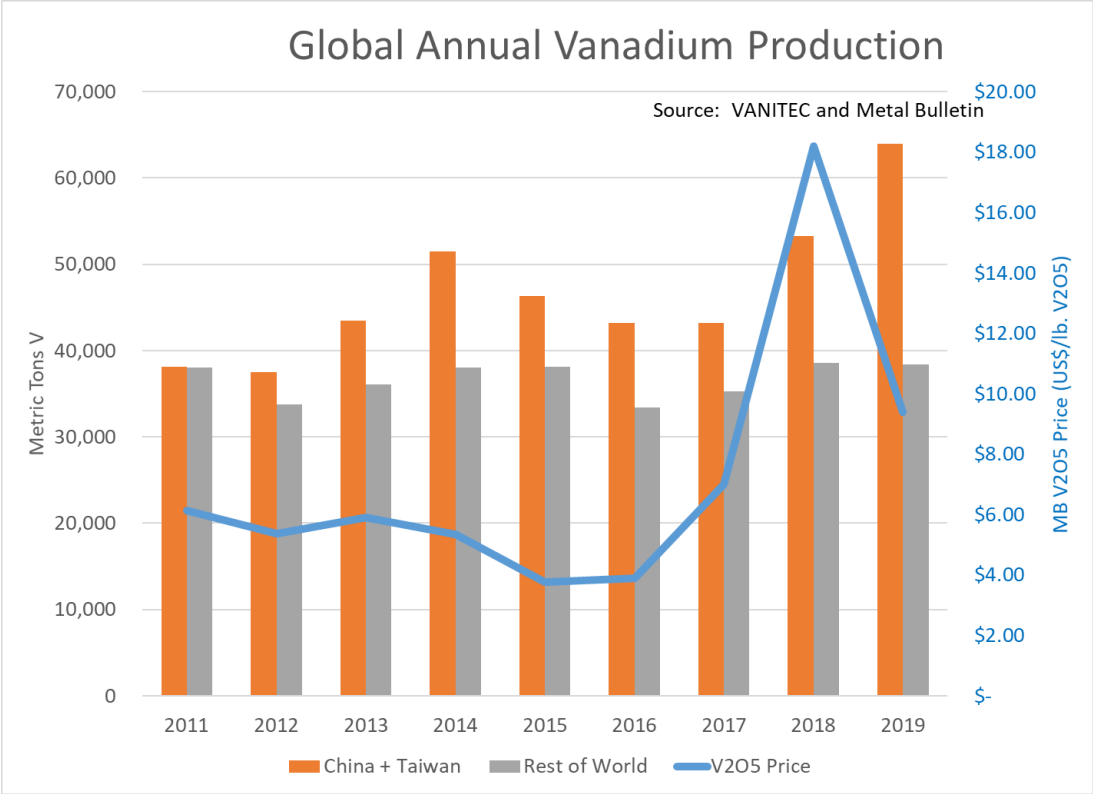


Coproduct vanadium slag generated at 14 steel mills in China, Russia and New Zealand generate the raw material for 69% of vanadium production in 2019. China's share of the global vanadium production continued to grow in 2019 reaching 59% of the total.


Global Annual Vanadium Production by Country
120,000
100,000
80,000
60,000
40,000
20,000
-
MTV
$25.00
$20.00
$15.00
$10.00
$5.00
$-
V2O5 Price (US$/lb V2O5)
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
China
Russia
South Africa
North America
Europe
Japan
Korea
Taiwan
India
Australia
Brazil
Vietnam
V2O5 Price
Source: TTP Squared, Inc.

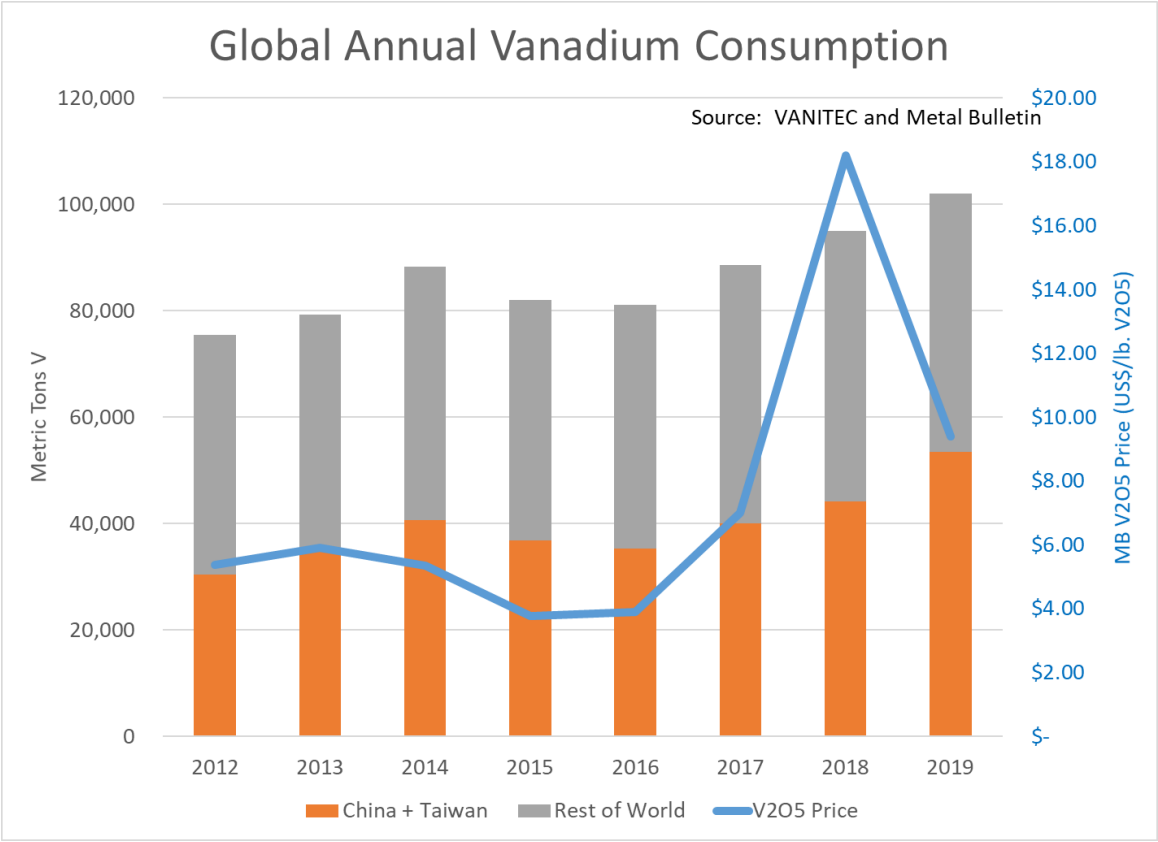
Global Annual Vanadium Production



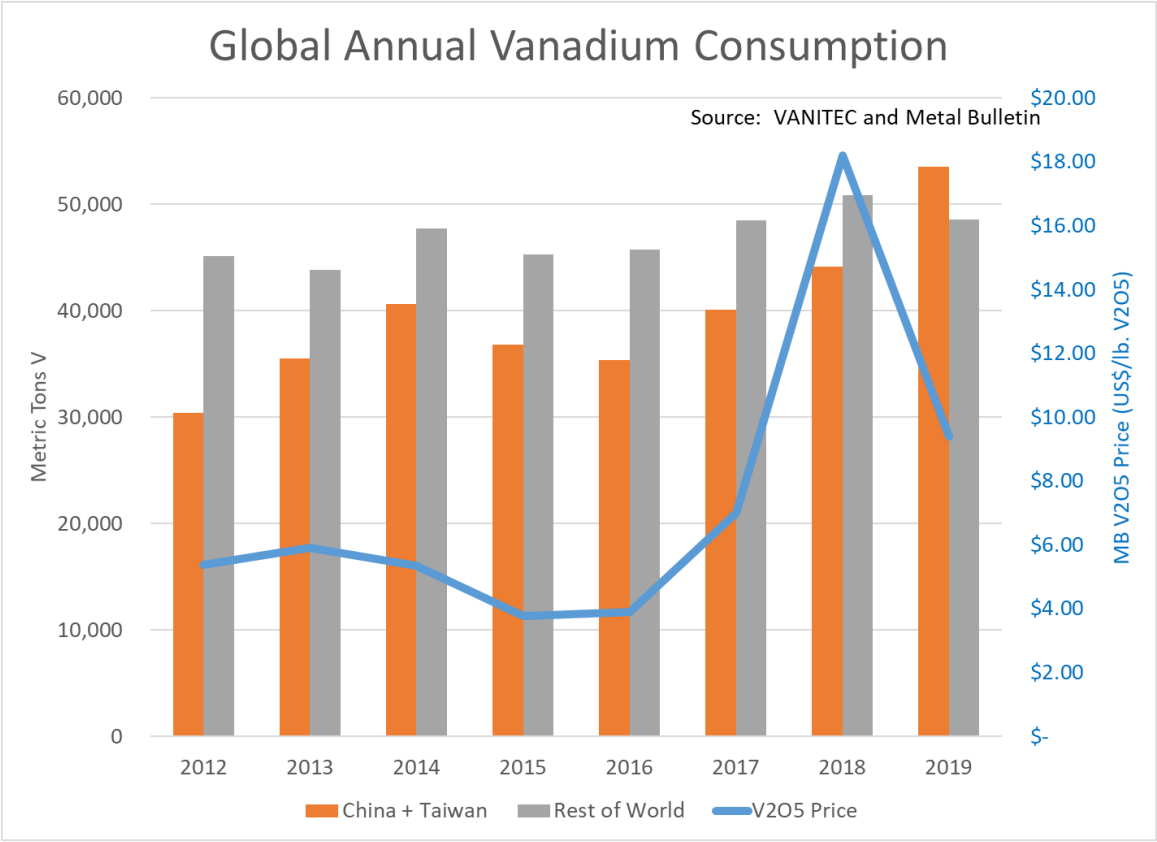


Global vanadium production grew from 76,166 metric tons pure vanadium (MTV) in 2011 to 102,365 MTV in 2019 for a compound annual growth rate (CAGR) of 3.8%.

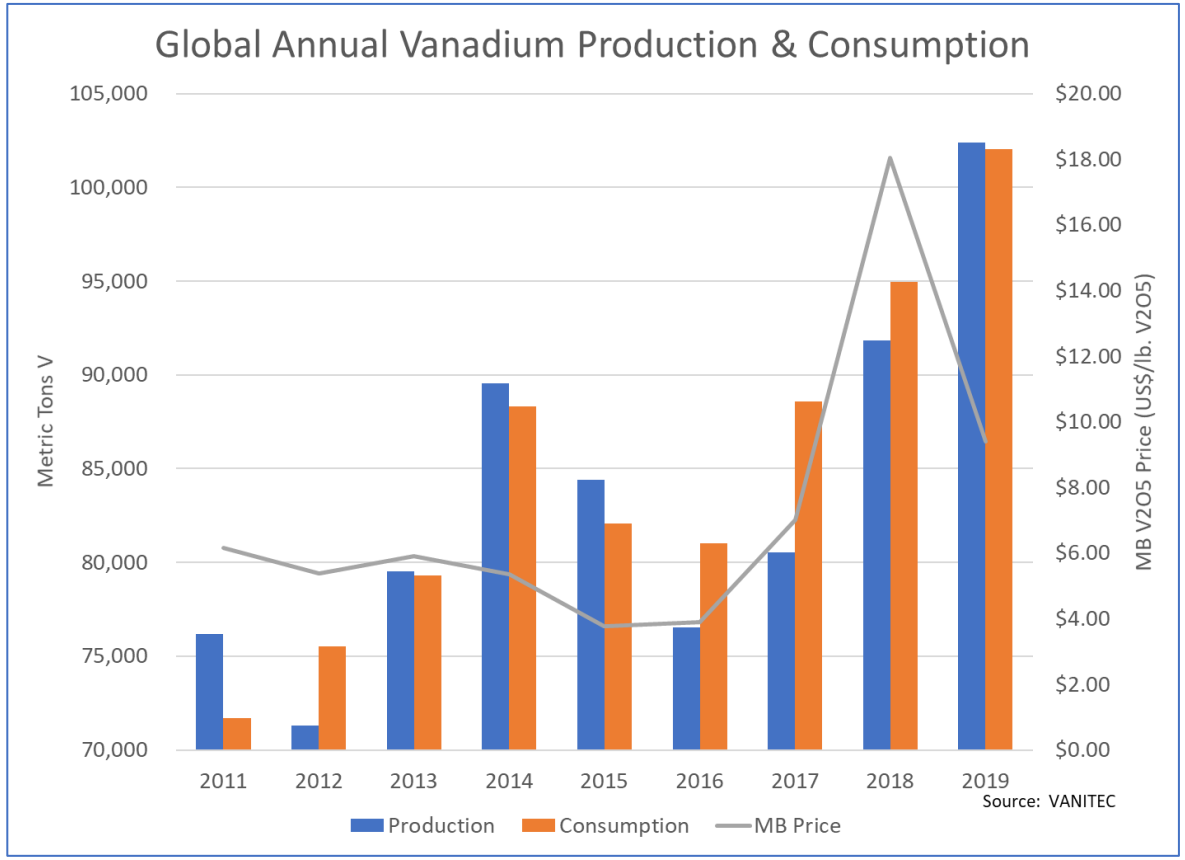
Essentially all the growth in production over the period 2011-2019 occurred in China. Ex China + Taiwan vanadium production was 38,066 MTV in 2011 and 38,427 MTV in 2019 for a CAGR of 0.1%. In China Vanadium production increased from 38,100 MTV in 2011 to 63,938 MTV in 2019 for a CAGR of 6.7%. There has been a strong correlation between vanadium prices and changes in Chinese production levels.

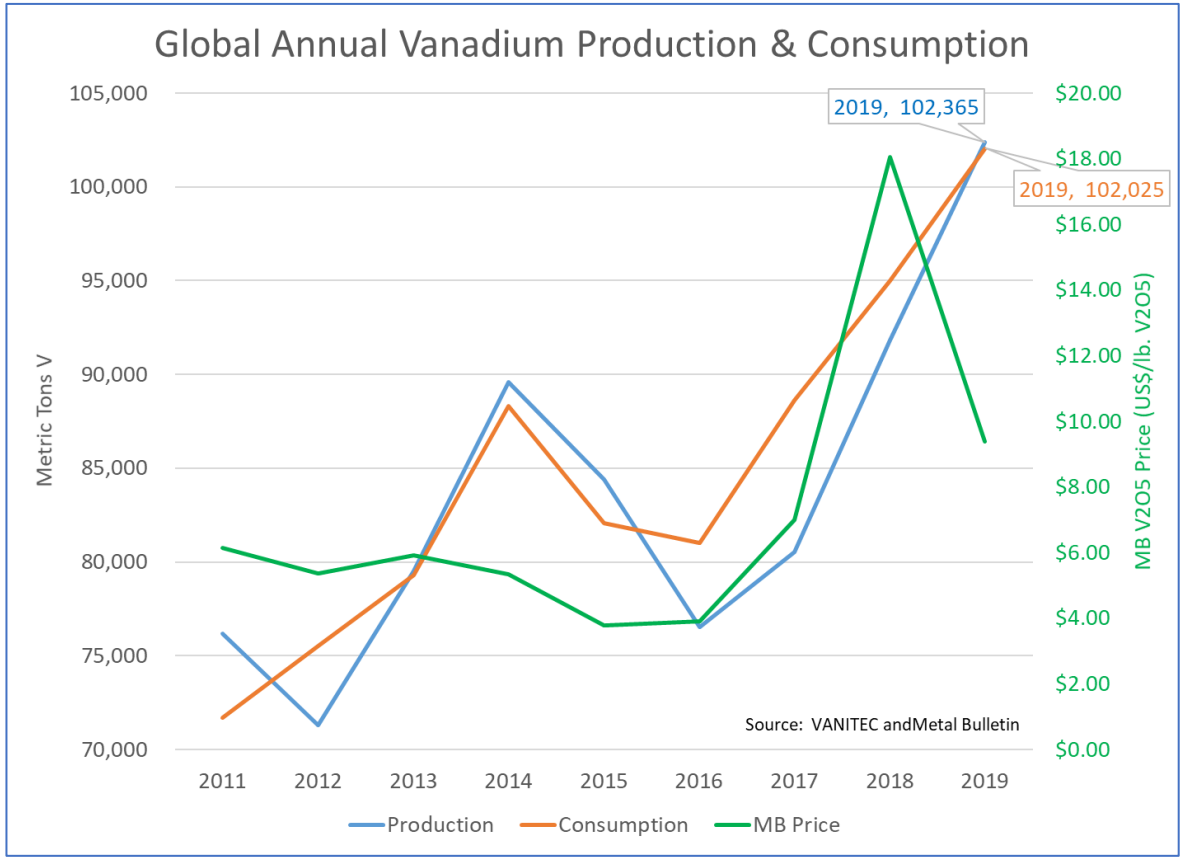


Global vanadium consumption grew from 71,700 MTV in 2011 to 102,025 MTV in 2019 for a CAGR of 4.5%. Global consumption dropped from 2014 to 2016 on the back of illegal substitution of quench and temper steel for high strength vanadium steel in Chinese rebar. The modification of the Chinese standards for rebar addressed this issue and also resulted in an ongoing increase in the amount of rebar produced in China requiring vanadium.

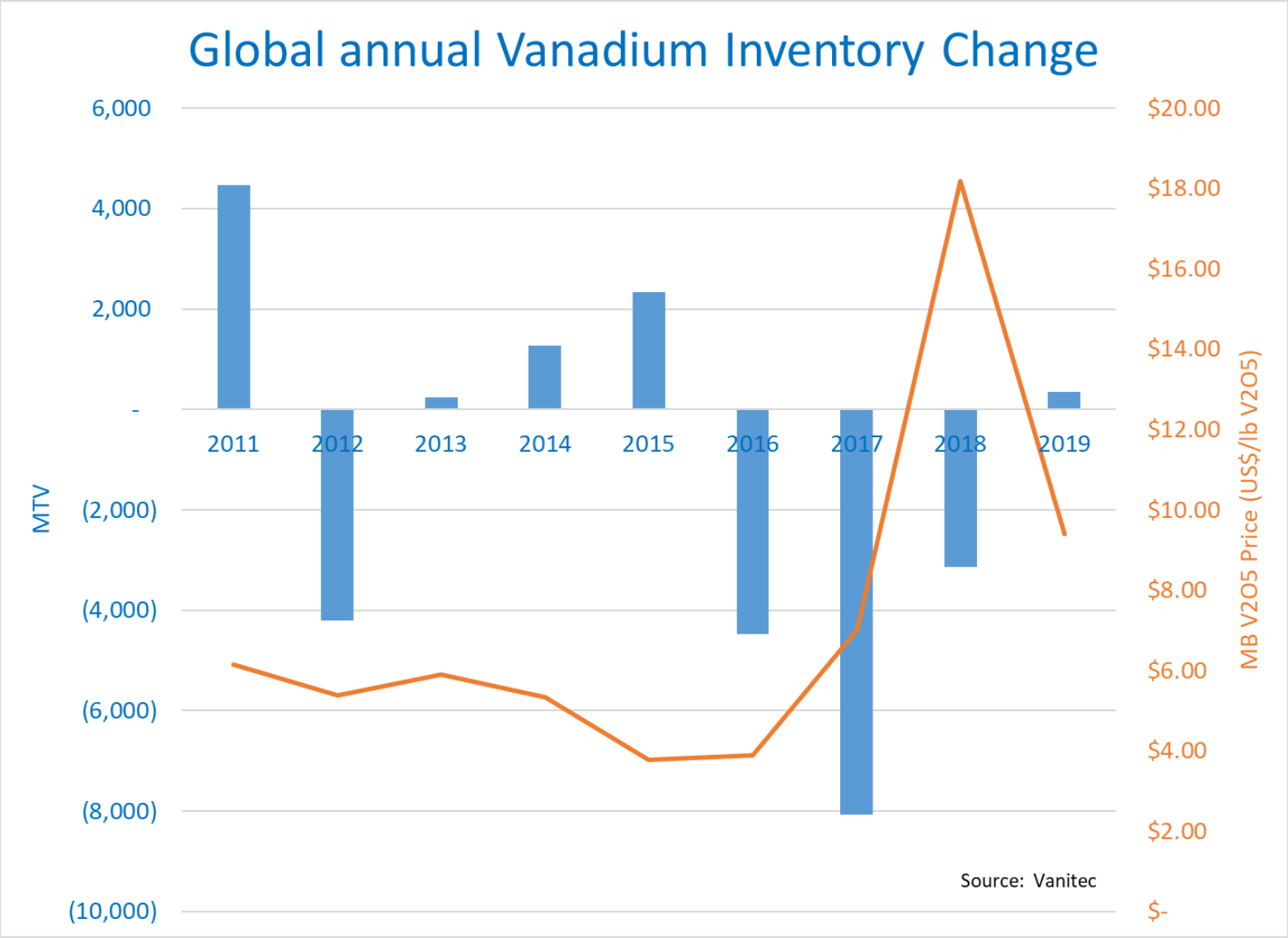


Ex China + Taiwan vanadium consumption grew from 45,100 MTV in 2011 to 48,525 MTV in 2019 for a CAGR of 0.9%. In China + Taiwan vanadium consumption grew from 30,400 MTV in 2011 to 53,500 MTV in 2019 for a CAGR of 7.3%. The vast majority of growth in global vanadium consumption is a result of increase use in Chinese rebar applications.

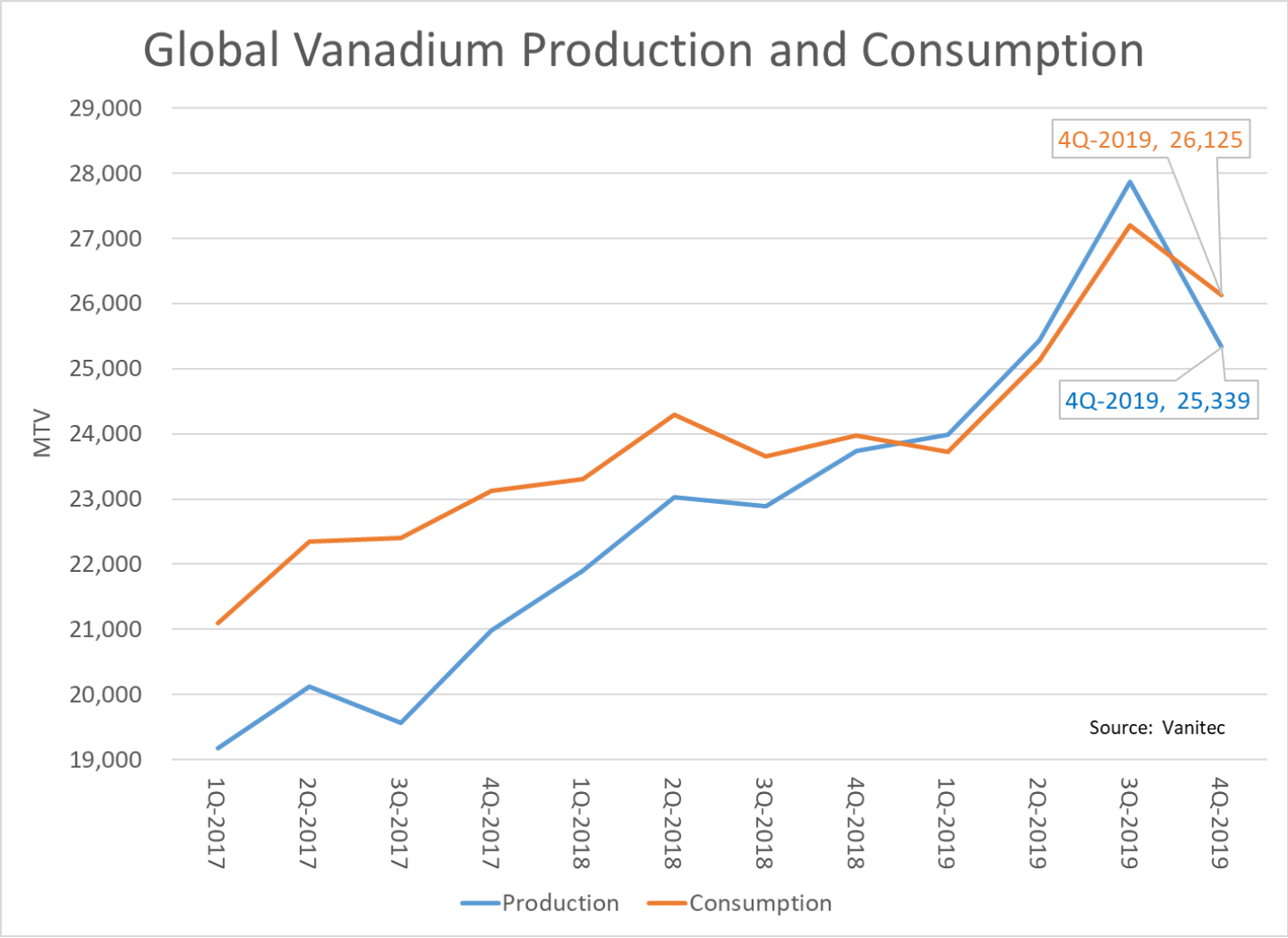




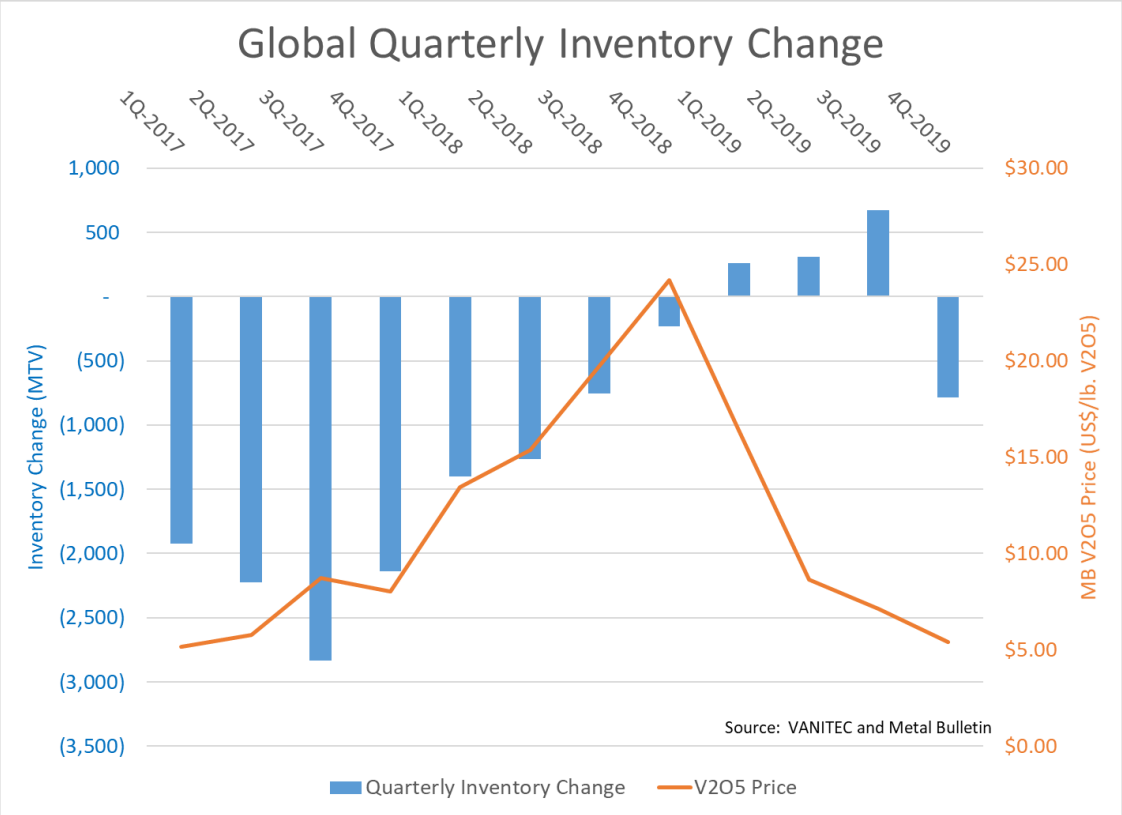
Looking at the relationship between global vanadium production and consumption on an annual basis, we see that global consumption was above production from 2014-2018. In 2019 production slightly exceeded consumption.

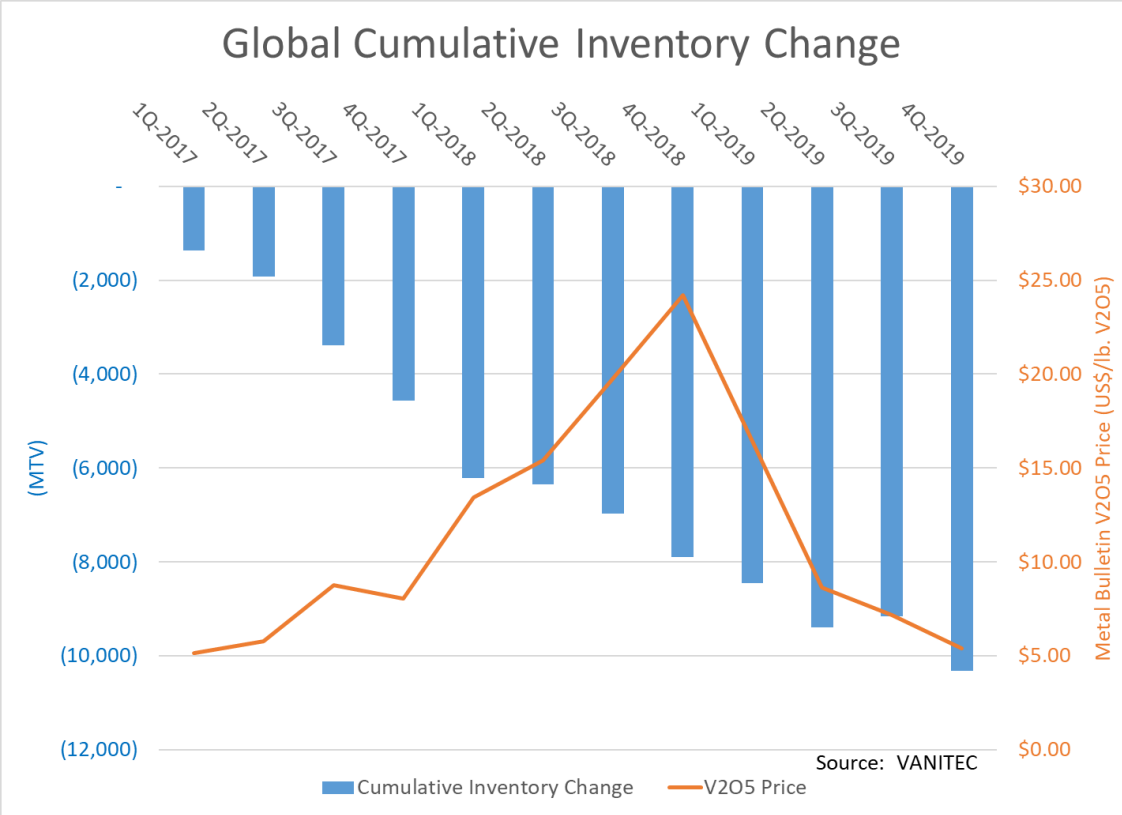


Global vanadium inventories decreased each year from 2016 to 2018. in 2019 global inventories increased slightly.



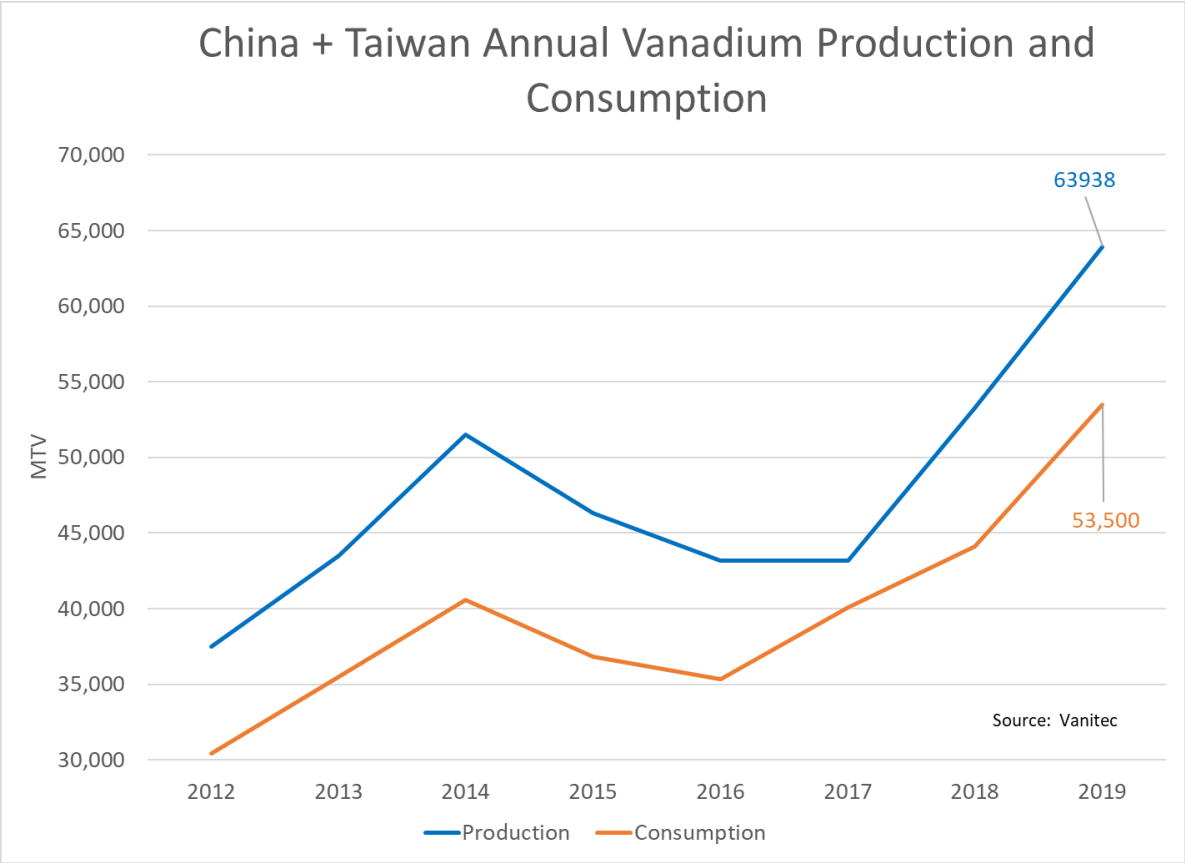
If we look at global vanadium production and consumption on a quarterly basis, we see that in the first three quarters of 2019 vanadium production exceeded consumption. In the fourth quarter both production and consumption decreased with Q4 production falling short of Q4 consumption by 786 MTV.

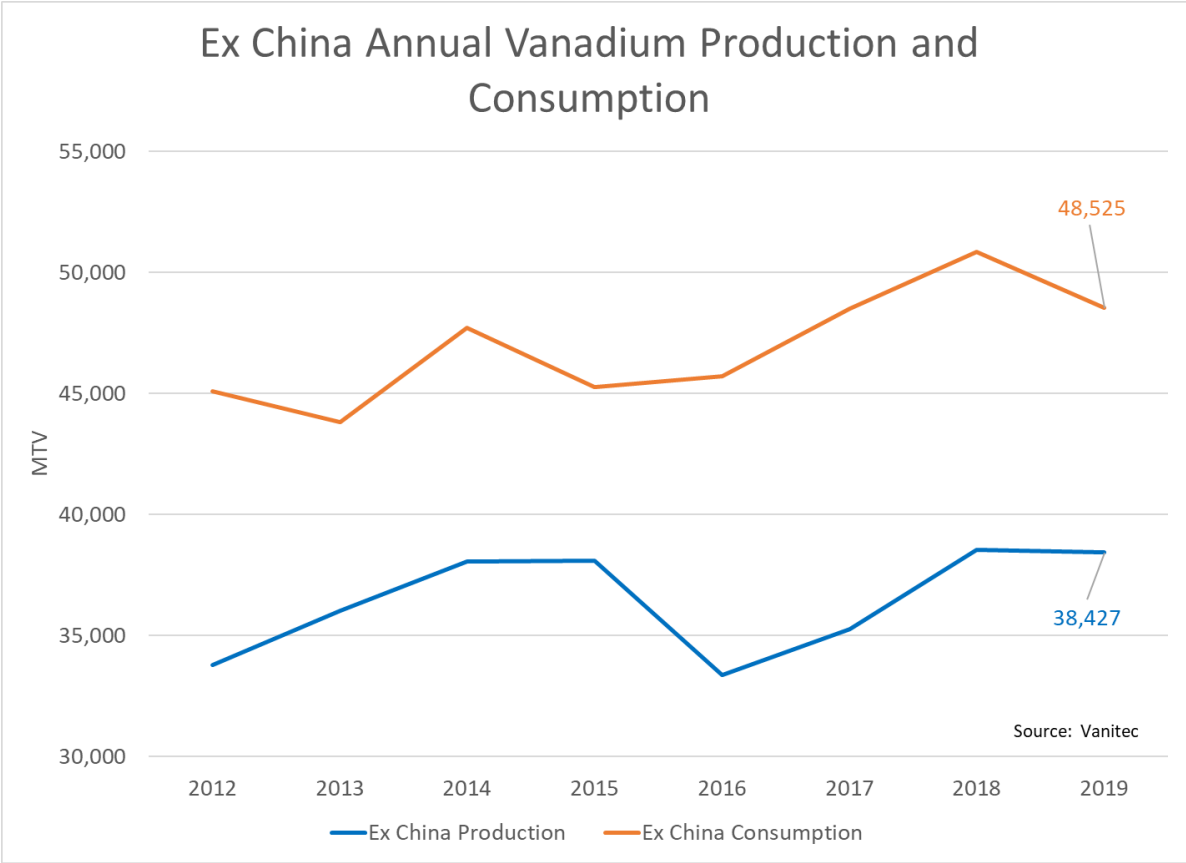




Looking at global inventory change on a quarterly basis we see that in the first three quarters of 2019 global inventories grew, but in the last quarter inventories decreased.

If we look at the change in global inventory from Jan 1, 2017 until Dec. 31, 2019 we see that there has been a drawdown of more than 10,000 MTV of inventory over this period.

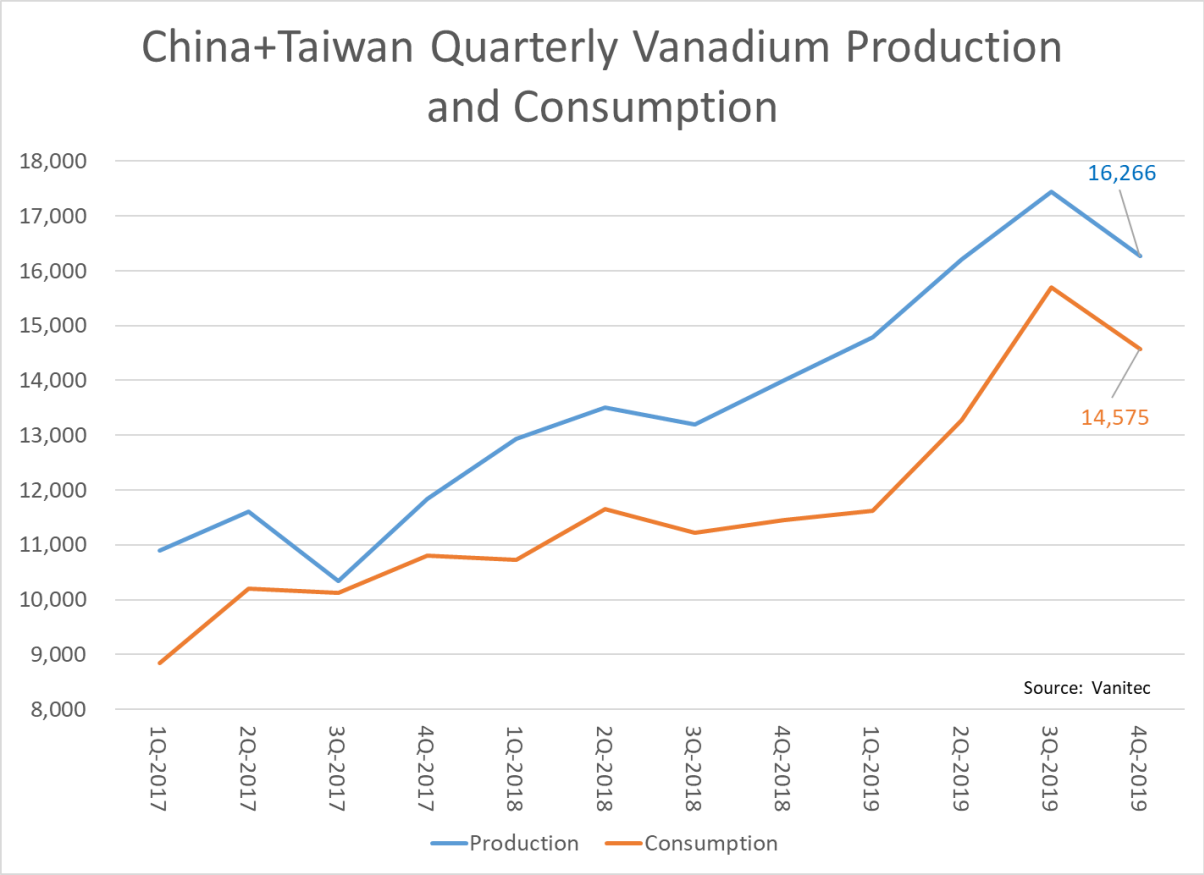


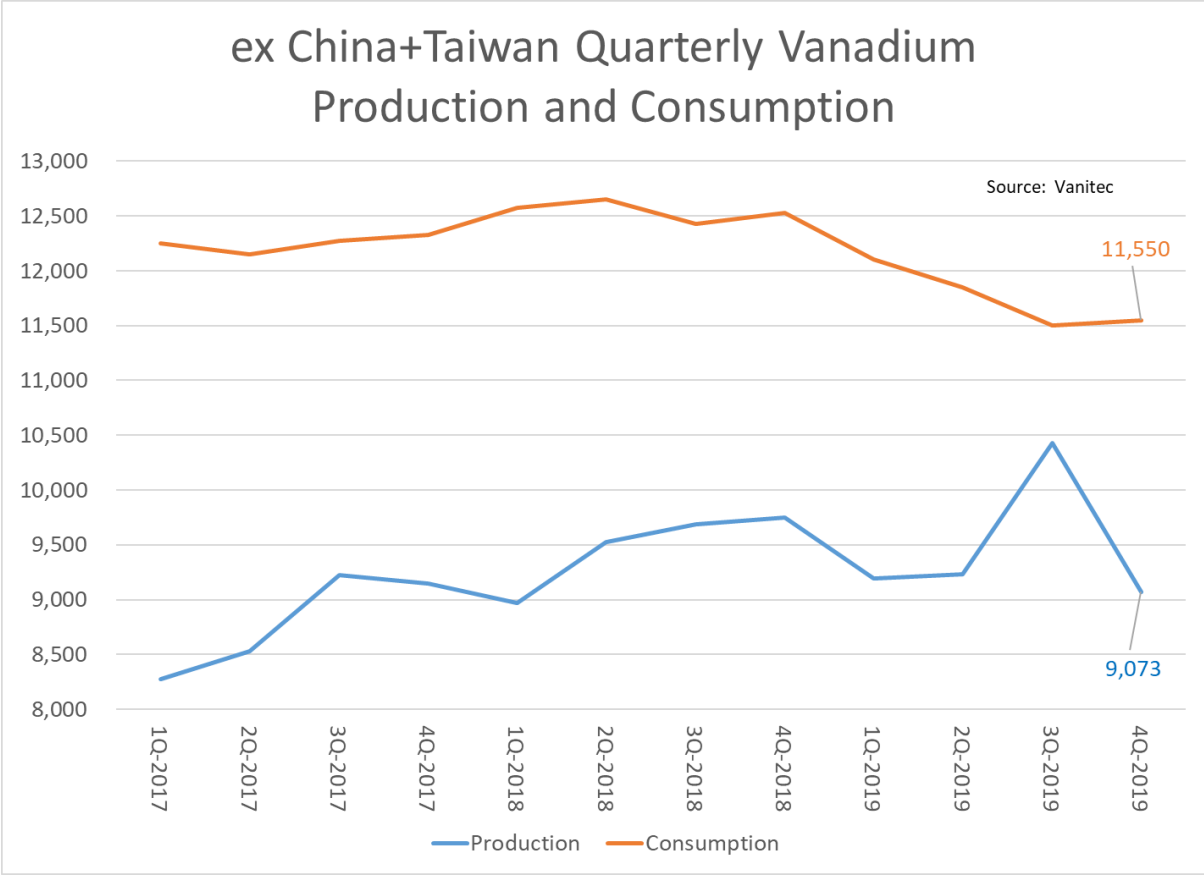


Looking at annual data from 2012 to 2019 for mainland China + Taiwan production has exceeded consumption by between 3,000MTV and 11,000 MTV each year. In 2019 production exceeded consumption by 10,438 MTV.

Historically vanadium consumption outside of China + Taiwan is 7,000 to 13,000 MTV more than production each year. In 2019 on an annual basis vanadium consumption ex China + Taiwan was 10,098 MTV above production ex China + Taiwan.

On an annual basis the data would suggest a very balanced global market in terms of production and Consumption

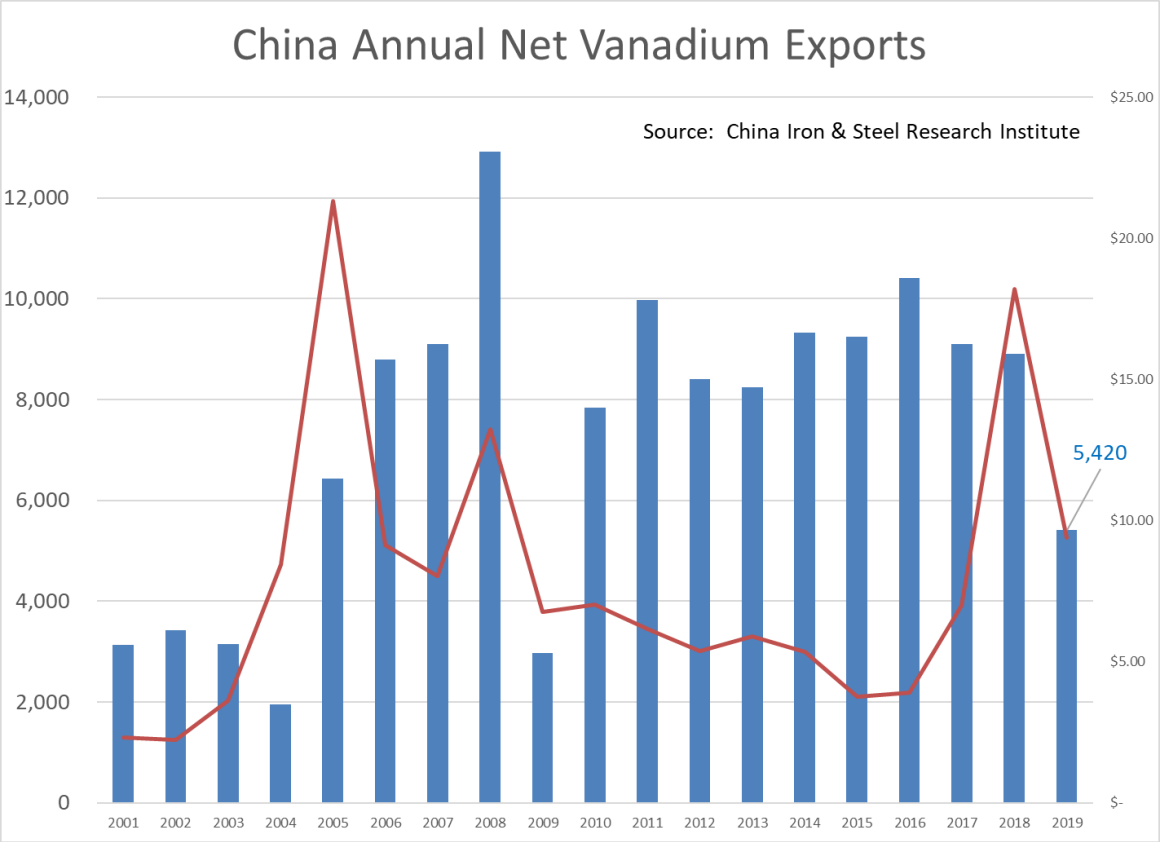




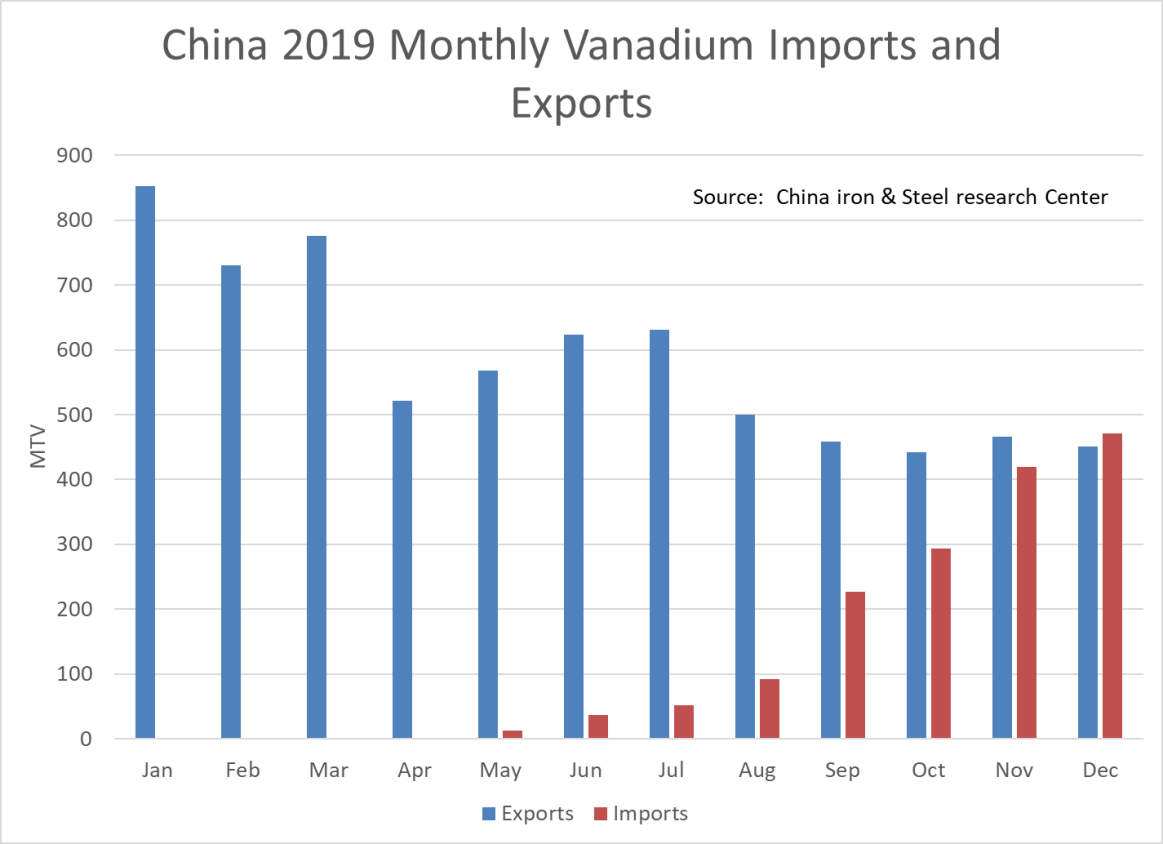
In 4Q-2019 Vanitec data shows vanadium production in mainland China + Taiwan was 1,691 MTV above consumption in mainland China and Taiwan. On an annualized basis this would suggest material available for export from mainland China of 6,764 MTV.

Outside of China + Taiwan we see that consumption of vanadium exceeded production by 2,477 MTV in 4Q-2019. This is equal to an annualized rate of 9,908 MTV per year.

On a quarterly basis 4Q-2019 data suggests inadequate net exports from China to meet western market requirements.



China Net exports of vanadium from 2012-2018 were sufficient to meet the demand outside of China that could not be met with vanadium production from outside of China. However, in the second half of 2019 Chinese net exports have decreased significantly.



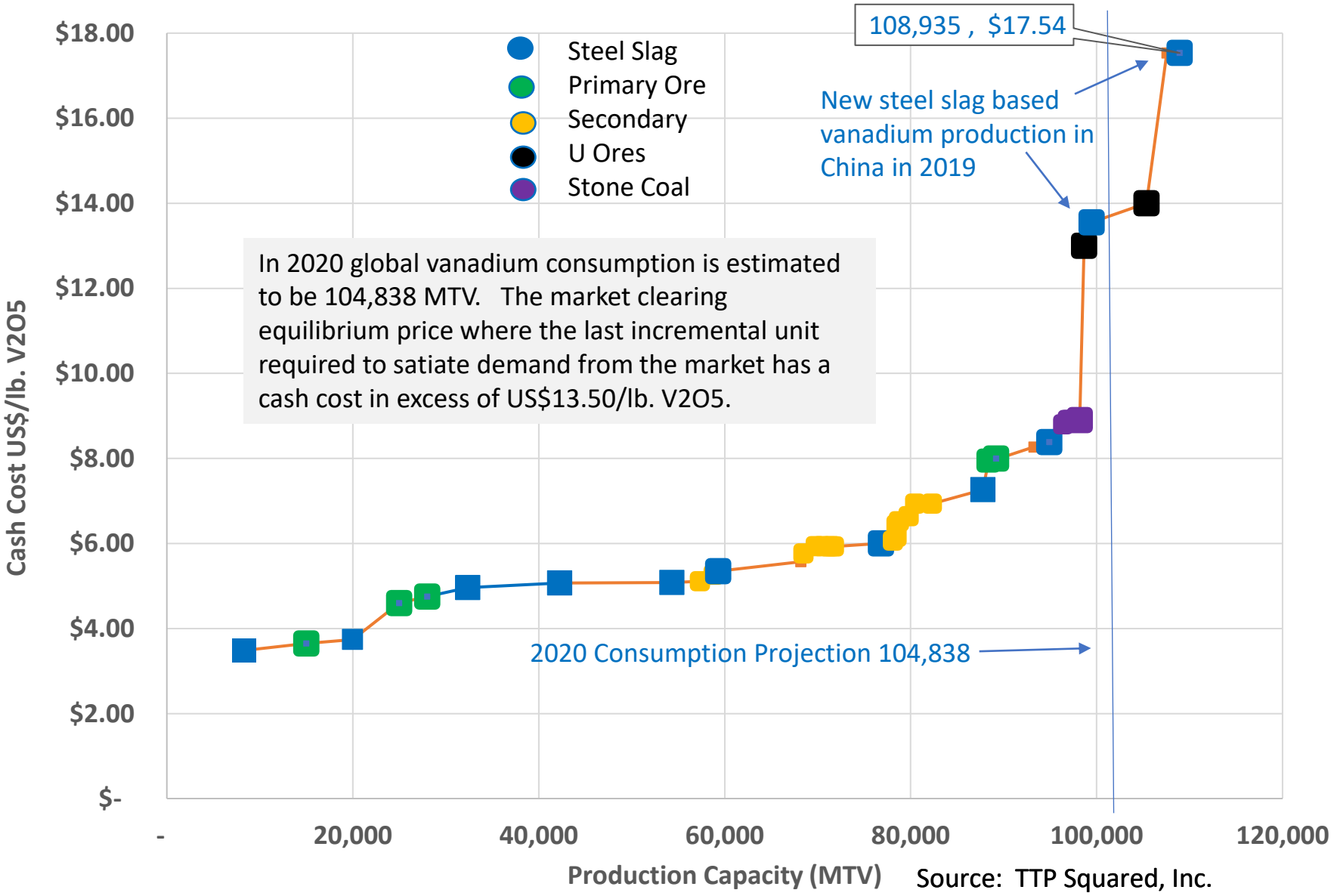
Imports of vanadium into China surged in 2H-2019 while exports decreased. Looking at net exports from China + Taiwan on a monthly basis we see China was a net importer of vanadium in December 2019. In January and February 2020 we see net exports recovering to a rate of 233 MTV per month or 700 MTV per quarter as compared to the deficit ex China in 4Q-2019 of 2,477 MTV.

Mainland China Vanadium exports

- Historically the world ex China requires 8,000-10,000 MTV per year in net exports from China to maintain balance in western markets.
- High prices in 2018 caused significant loss of market share to niobium in the west that will take time to regain, but still we project an ongoing deficit in production versus consumption of vanadium ex China.
- China net exports of vanadium have been dropping rapidly and in Q42019 were at a rate of less than 800 MTV per year.
- Chinese exports depend on the continuation of production with cash costs well above current market prices.

Source: TTP Squared, Inc.

2020 V2O5 Cash Cost Curve



Source: TTP Squared, Inc.

Vanadium Market Analysis - Key Highlights

- Essentially all the growth in both consumption and production of vanadium from 2011-2019 occurred in China.
- Production of vanadium in 2019 was slightly higher than consumption while in the years 2016-2018 consumption exceeded production.
- If we look at Q42019 we see once again consumption rising above production globally.
- The world ex China consistently has a deficit in vanadium production as compared to consumption, and as a result Chinese exports are required to keep the market in balance.
- Growing consumption of vanadium in China is having a huge impact on the availability of Chinese exports.
- In history China has only been a net importer of vanadium in one time period – 1Q-2004 – which precipitated the vanadium price spike of 2004-2005.

Source: TTP Squared, Inc.

China Rebar


China Monthly Rebar Production
Total China Rebar Production
10,000 MT
2,400
2,200
2,000
1,800
1,600
1,400
1,200
1,000
Dec-19, 2,186
Jun-19, 2,269
Feb-19, 1,606
Feb-18, 1,491
Feb-17, 1,330
Feb-16, 1,350
Feb-15, 1,458
Feb-14, 1,556
Source: China Iron & Steel Research Institute (CISRI)
Jan-14
Apr-14
Jul-14
Oct-14
Jan-15
Apr-15
Jul-15
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
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Jul-18
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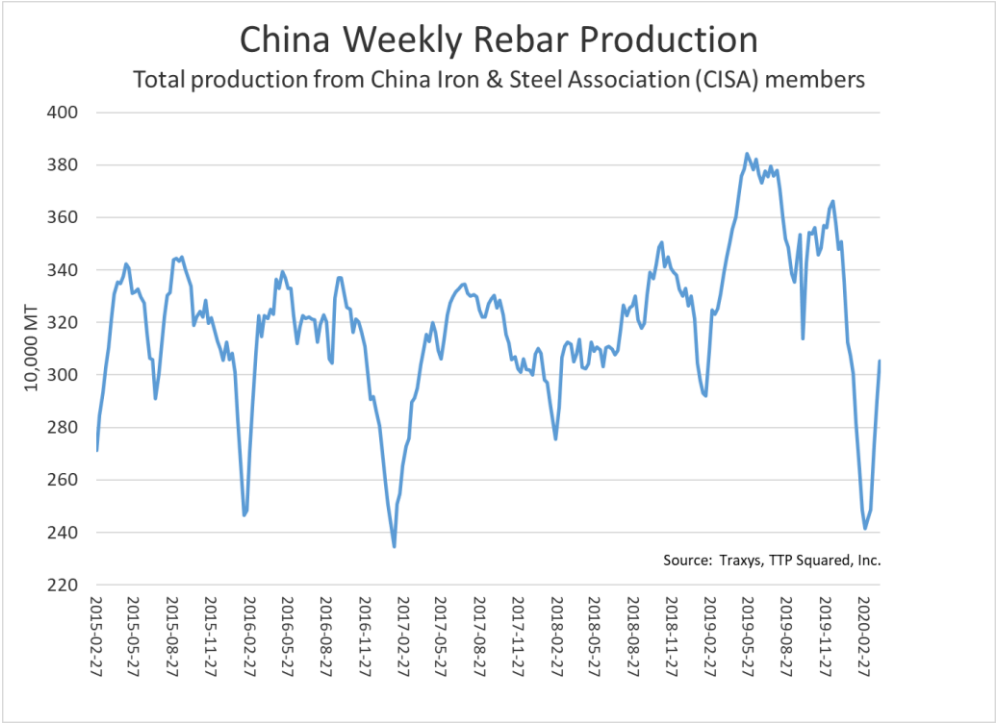
Apr-19
Jul-19
Oct-19
Series1
12 per. Mov. Avg. (Series1)


China Weekly Rebar Production
Total production from China Iron & Steel Association (CISA) members
10,000 MT
400
380
360
340
320
300
280
260
240
220
Source: Traxys, TTP Squared, Inc.
2015-02-27
2015-05-27
2015-08-27
2015-11-27
2016-02-27
2016-05-27
2016-08-27
2016-11-27
2017-02-27
2017-05-27
2017-08-27
2017-11-27
2018-02-27
2018-05-27
2018-08-27
2018-11-27
2019-02-27
2019-05-27
2019-08-27
2019-11-27
2020-02-27


China Weekly Rebar Consumption
10,000 MT
500.00
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
-
Source: Traxys, TTP Squared, Inc.
2015-02-27
2015-05-27
2015-08-27
2015-11-27
2016-02-27
2016-05-27
2016-08-27
2016-11-27
2017-02-27
2017-05-27
2017-08-27
2017-11-27
2018-02-27
2018-05-27
2018-08-27
2018-11-27
2019-02-27
2019-05-27
2019-08-27
2019-11-27
2020-02-27
4/3/2020
TTP Squared, Inc.
18


China Rebar Inventory
10,000 MT
2,250.00
2,050.00
1,850.00
1,650.00
1,450.00
1,250.00
1,050.00
850.00
650.00
450.00
250.00
Source: Traxys, TTP Squared, Inc.
2015-02-27
2016-02-27
2017-02-27
2018-02-27
2019-02-27
2020-02-27

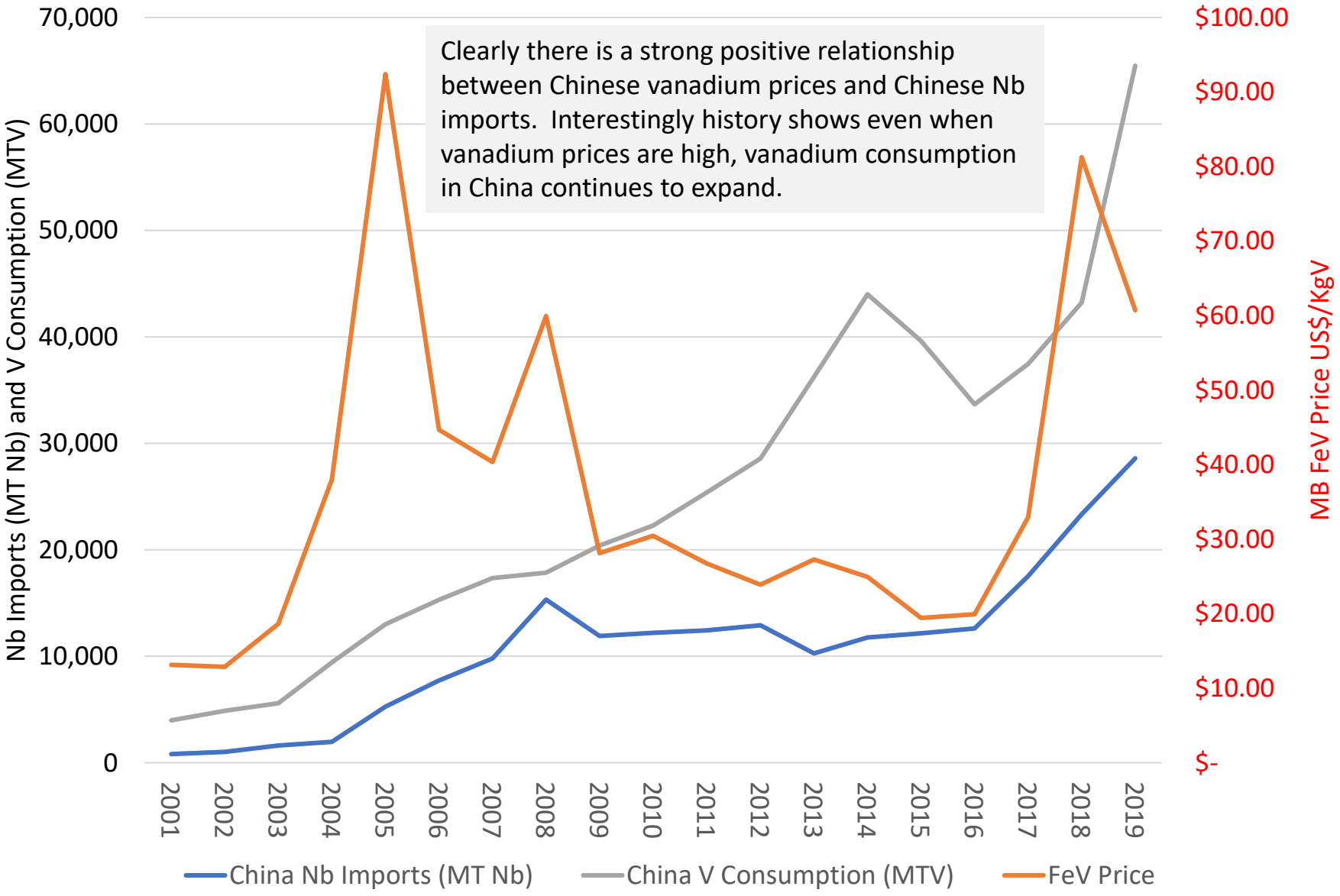
China Rebar Market

- Production of steel reinforcing bars used in concrete construction in China surged to 241 million MT in 2019 as compared to 211 million MT in 2018.
- As we exited the Chinese New Year we saw the traditional patterns of production, consumption and inventories being disrupted by the virus.
- As a result of the COVID-19 virus rebar inventory reached a high level and production reached a low level in January and February.
- Production and consumption of rebar in China are now accelerating and inventories are decreasing as the construction industry comes back to work following the virus.

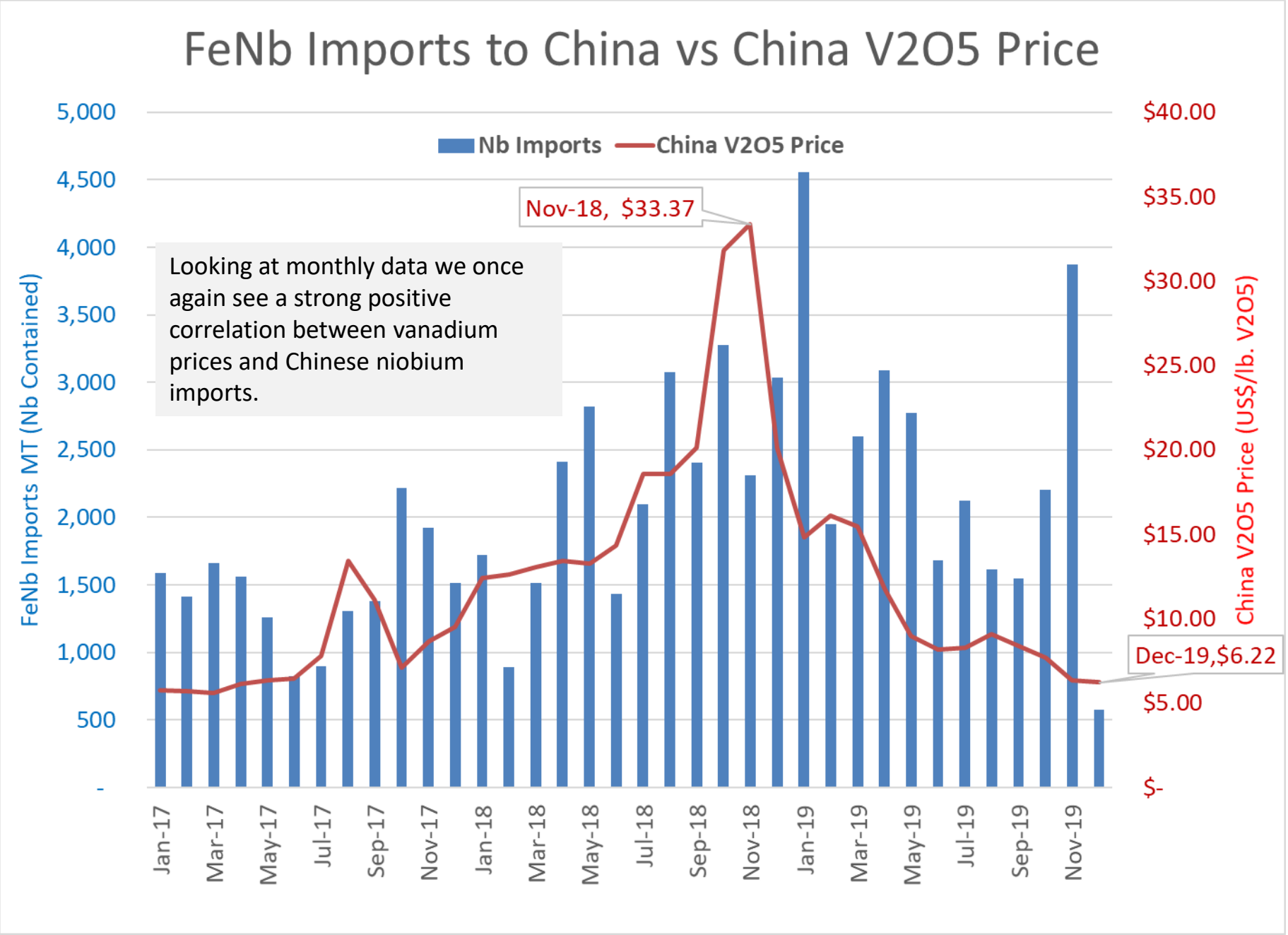
Source: TTP Squared, Inc.

Substitution of Nb for V

FeNb Imports to China vs MB FeV Price

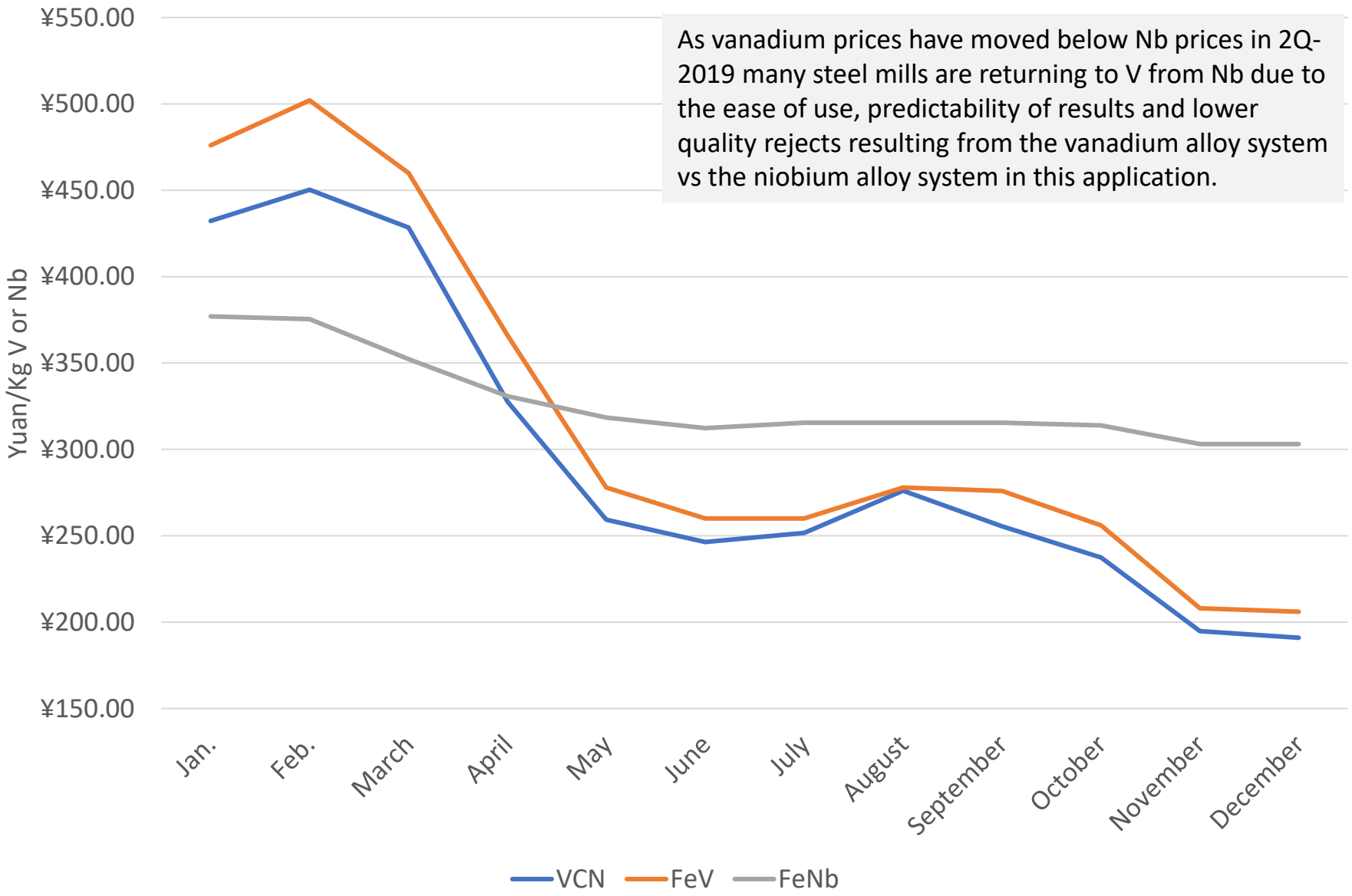


Source: China Iron & Steel research Institute, Metal Bulletin



Source: China Iron & Steel Research Institute, TTP Squared, Inc.

V and Nb Prices in China



As vanadium prices have moved below Nb prices in 2Q-2019 many steel mills are returning to V from Nb due to the ease of use, predictability of results and lower quality rejects resulting from the vanadium alloy system vs the niobium alloy system in this application.

Source: www.ferroalloynet.com

Substitution of Niobium for Vanadium

- Today vanadium prices in China are below niobium prices. Given the fact that the specific consumption rate of vanadium and niobium are very similar in grade 3 rebar, it is reasonable to believe some steel mills making grade 3 rebar who replaced vanadium with niobium in late 2018 and early 2019 are now returning to vanadium. Vanadium as compared to niobium in grade 3 rebar is easier to use, the results are more predictable, mill throughput is higher, energy consumption is lower and reject rates are lower.

Source: TTP Squared, Inc.

Substitution of Niobium for Vanadium

- From a practical standpoint it is impossible that niobium can replace vanadium in all high strength rebar applications in China.
  - Niobium can be used in small diameter grade 3 rebar but not in large diameter (≥25mm) grade 3 rebar.
  - Niobium CANNOT replace vanadium in grade 4, 5 or 6 rebar for metallurgical reasons.
- Assuming very high prices for vanadium relative to niobium there is a maximum substitution rate that is technically possible.
- In the end the adoption of the new rebar standard on November 1, 2018 in China means that MORE of BOTH vanadium and niobium will be required in the future.

Source: TTP Squared, Inc.

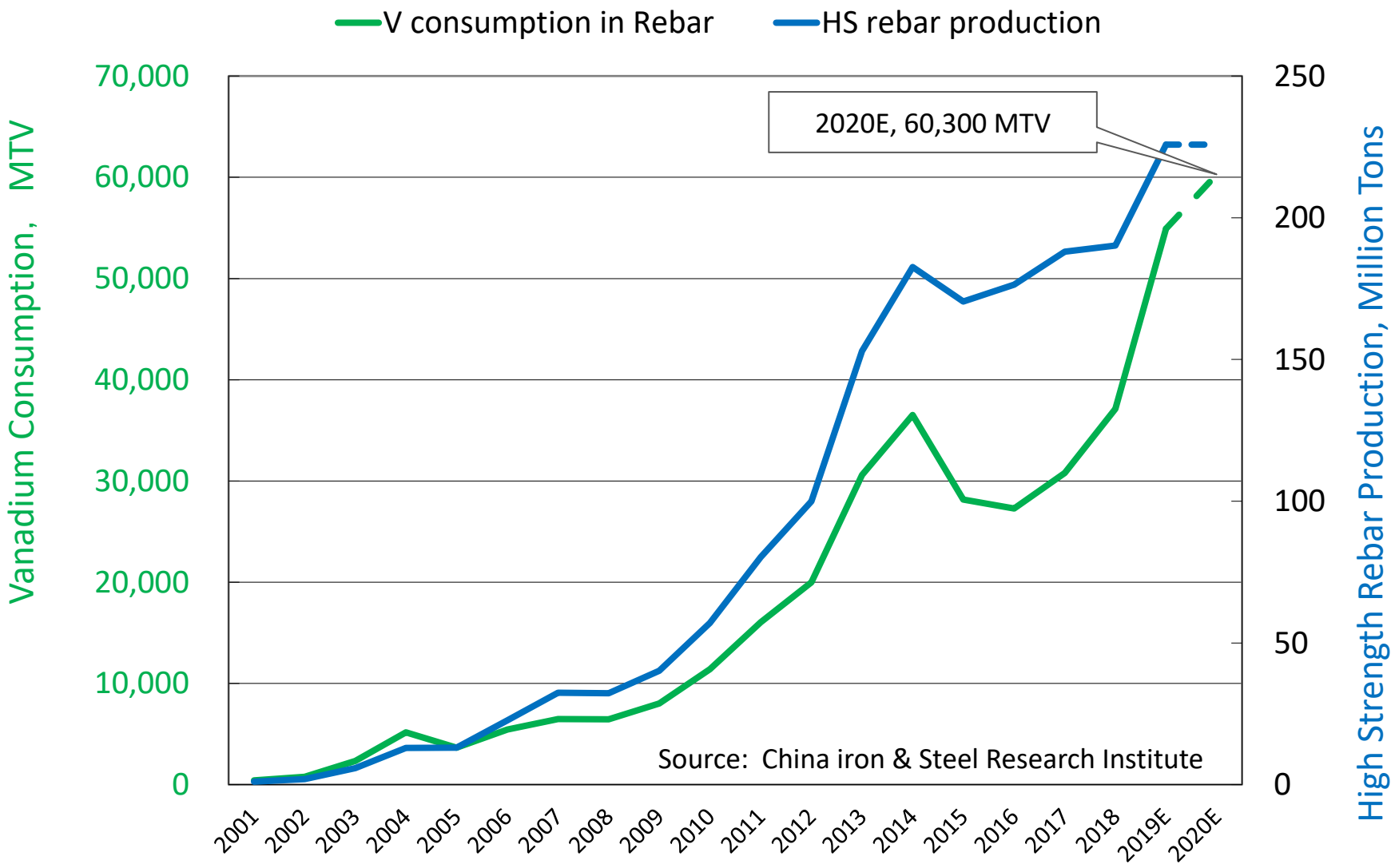
V and Nb Consumption in China 2019

	2019					
	Grade 3	**Grade 4**	**Grade 5**	**Other Apps**	**Total**	**Comments**
Rebar production (MT)	202,280,000	38,000,000	720,000		241,000,000	
≤10mm Diameter (%)	14%					Rebar with small diameter doesn't need V or Nb
≤10mm Diameter (MT)	28,319,200				28,319,200	
Total rebar> 10mm diameter (MT)	173,960,800	38,000,000	720,000		212,680,800	
Illegal Q&T steel (%)	30%	20%				CISRI estimates in 2019 30% of grade 3 and 20% of grade 4 was illegal Q&T steel.
Illegal Q&T steel (MT)	52,000,000	7,600,000			**59,600,000**	Q&T steel decreased over 2019 as conformance with the new standard increased.
Total Rebar using V and Nb	121,960,800	30,400,000				Total rebar less rebar with diameter <10mm less rebar produced using Q&T methods
FeNb consumption (MT)	10,009	-	-	29,231	39,240	CISRI estimates 10,000 MT FeNb we used in rebar in 2019
Nb consumption (MT Nb)	6,506	-	-	19,000	25,506	FeNb contains 65% Nb
Nb content of rebar (%)	0.020%					Nb content > 0.02% results in formation of brittle bainite structure with does not meet the standard
Total Nb rebar (MT)	32,530,670	-	-		32,530,670	
% of alloyed rebar using Nb	**19%**	0%	0%			
% of alloyed rebar using V	**51%**	100%	100%			total rebar > 10mm diameter less Q&T rebar less Nb rebar
Total V rebar (MT)	89,430,130	30,400,000	720,000		120,550,130	
V content of rebar (%)	0.029%	0.060%	0.100%			
V consumption (MTV)	**25,935**	**18,240**	**720**	**8,706**	**53,601**	84% of all vanadium consumption in China during 2019 was in rebar.

In 2019 it is estimated that still 52 million MT of grade 3 rebar and 7.6 million MT grade 4 rebar were produced using illegal quench & temper (Q&T) methods. The revised standard set in place Nov. 1 2018 was designed to eliminate this inferior steel from entering the market. Over time the adaptation of the specification has improved leading to growing vanadium consumption through 2019. looking forward eventually Q&T steel will be eliminated in favor of V and Nb microalloyed steel. **The elimination of Q&T steel should lead to an additional 12,000-20,000 MTV per year in vanadium consumption depending upon the relative prices of V and Nb.**

Source: China iron & Steel research Institute, TTP Squared, Inc.

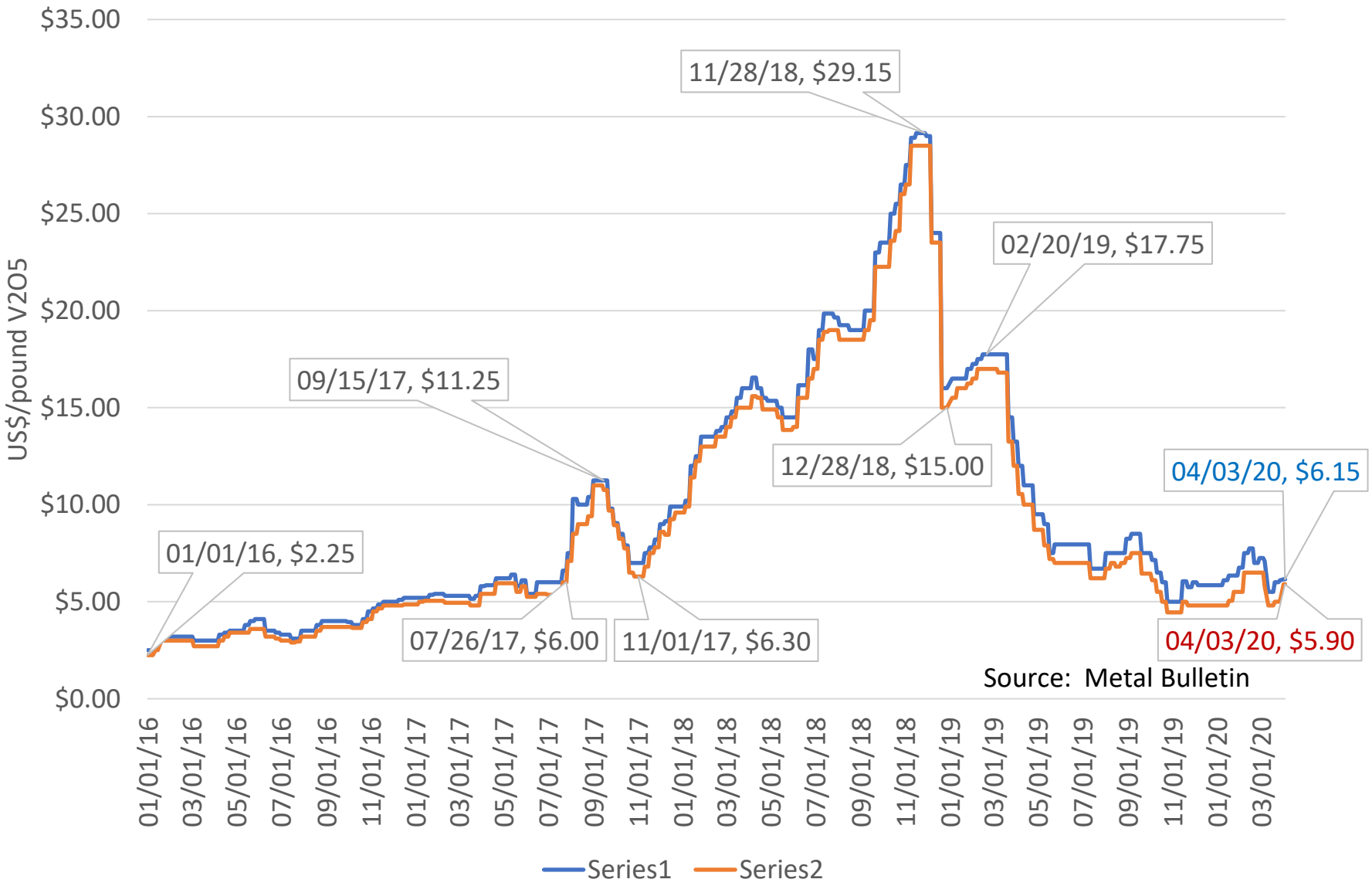
2001-2020 Vanadium Consumption in China Rebar



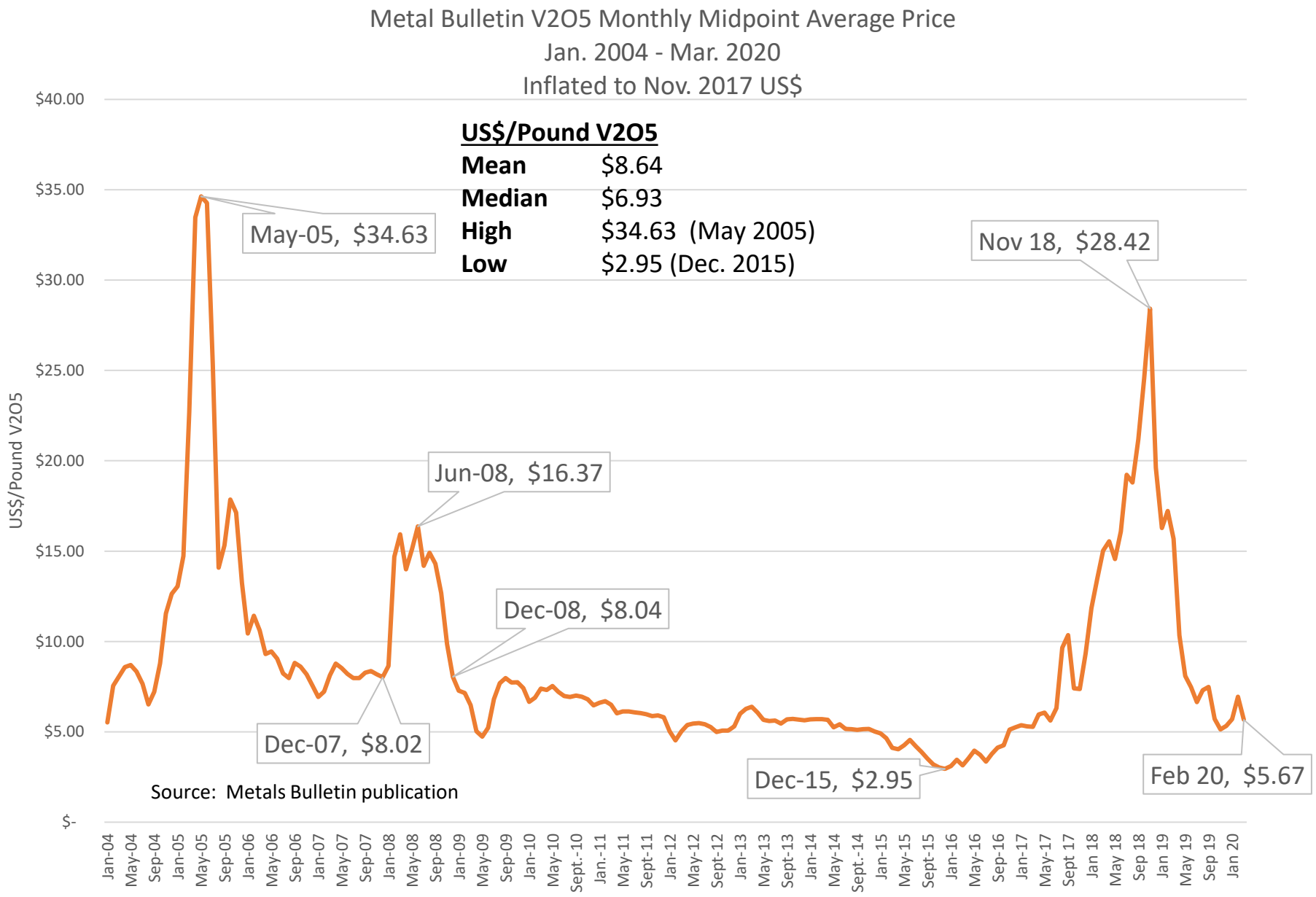
Source: China iron & Steel research Institute

Historical Price Data

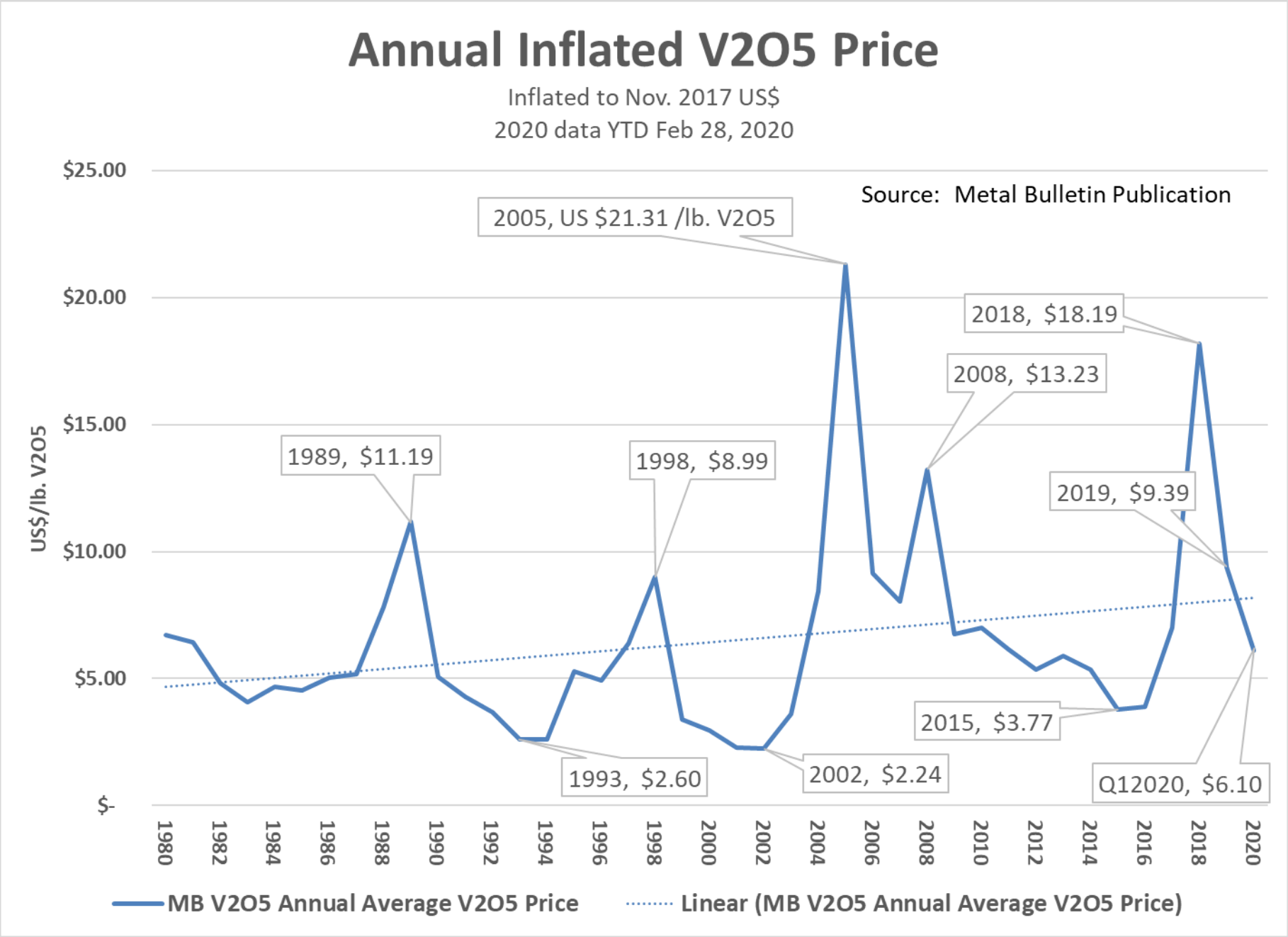
Metal Bulletin V2O5 Weekly Price Data



Source: Metal Bulletin

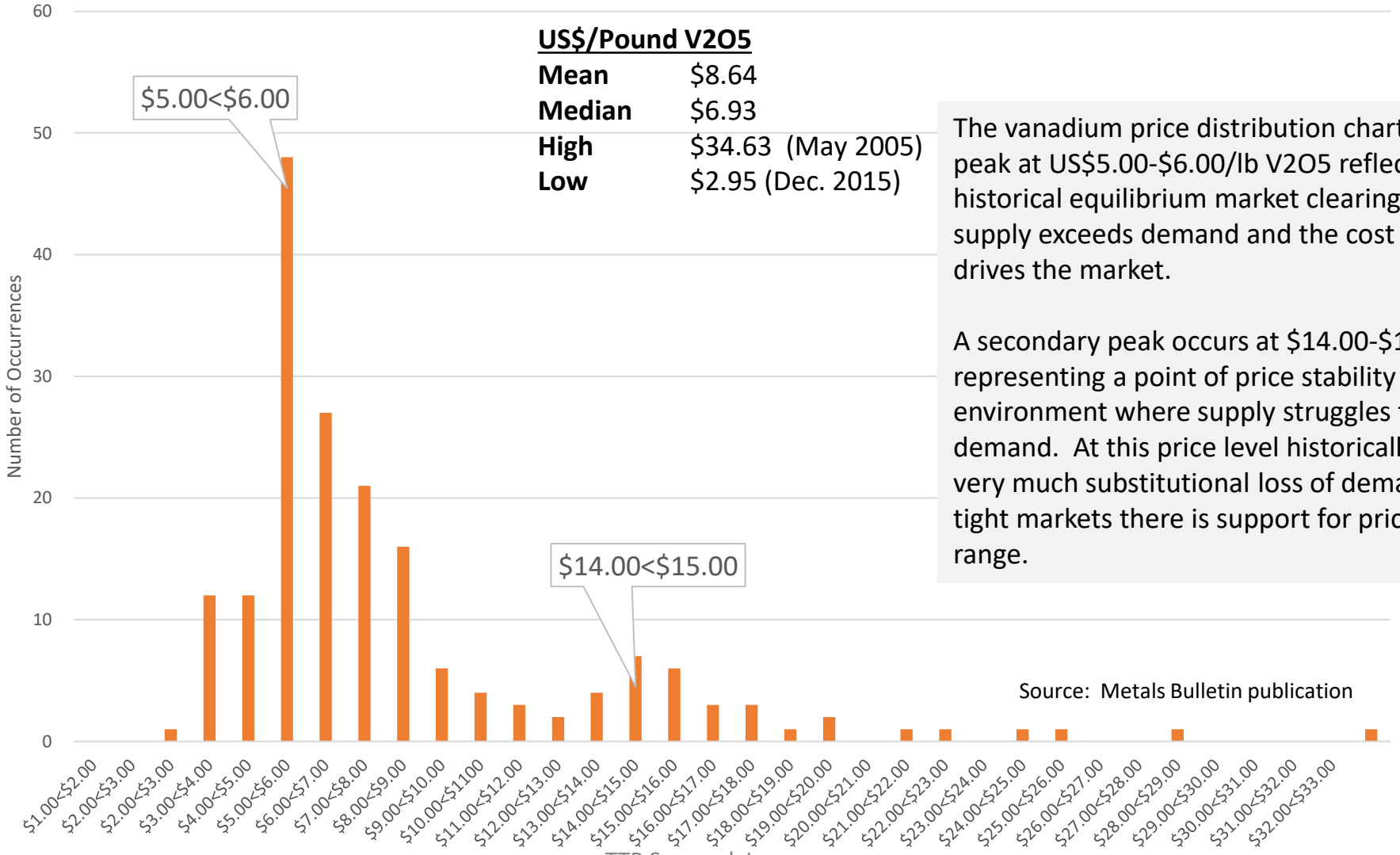


Source: Metal Bulletin, TTP Squared, Inc.



Source: Metal Bulletin, TTP Squared, Inc.

V2O5 Distribution Chart
Jan. 2004 - Mar. 2020
Inflated to Nov. 2017 US$



US$/Pound V2O5	
Mean	$8.64
Median	$6.93
High	$34.63 (May 2005)
Low	$2.95 (Dec. 2015)

The vanadium price distribution chart shows a clear peak at US$5.00-$6.00/lb V2O5 reflecting the historical equilibrium market clearing price when supply exceeds demand and the cost of production drives the market.

A secondary peak occurs at $14.00-$15.00/lb V2O5 representing a point of price stability in an environment where supply struggles to meet demand. At this price level historically we don't see very much substitutional loss of demand and so in tight markets there is support for prices in this range.

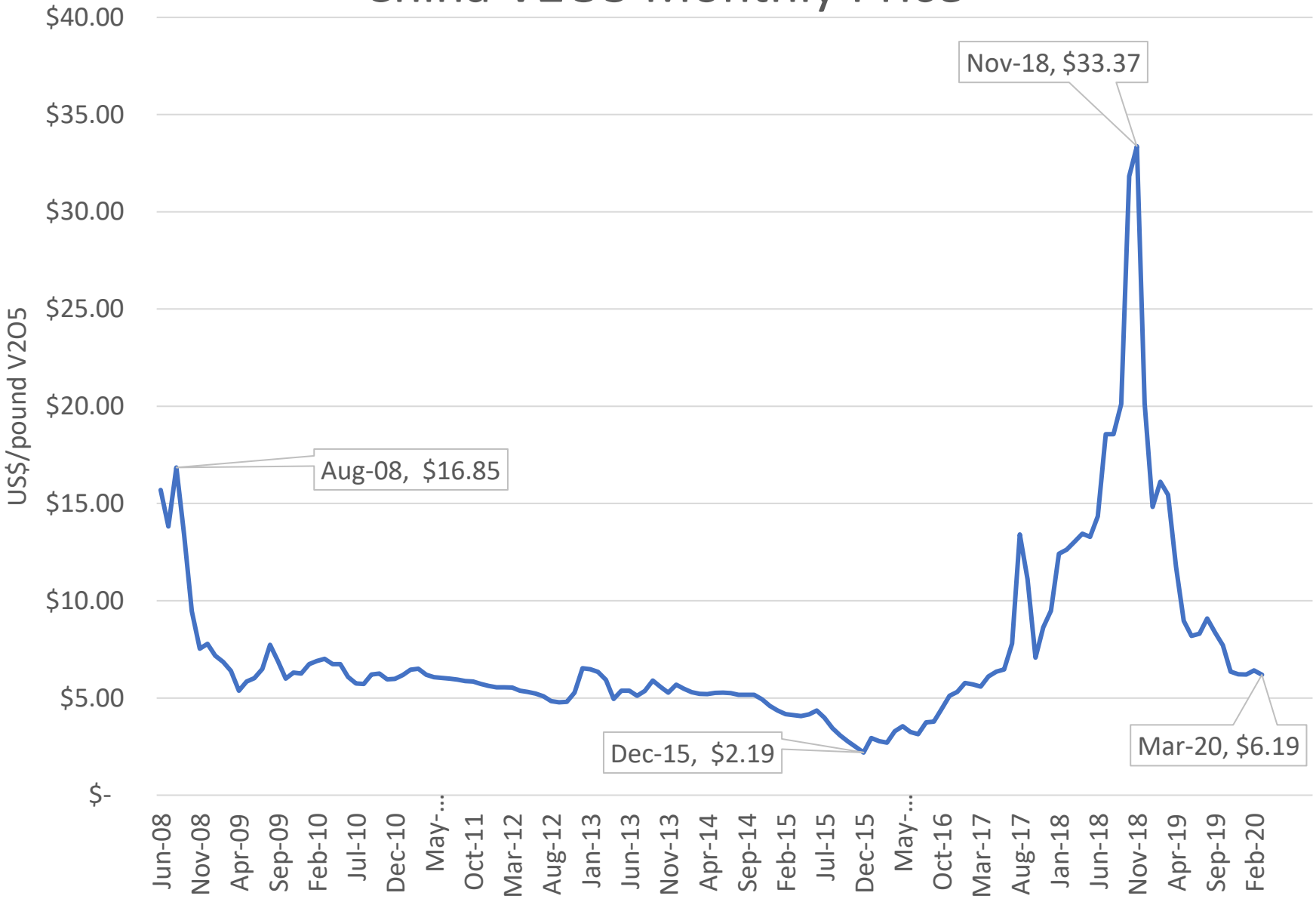
Source: Metals Bulletin publication

Source: Metal Bulletin, TTP Squared, Inc.

China V2O5 Daily Midpoint Price

Source: www.ferroalloynet.com

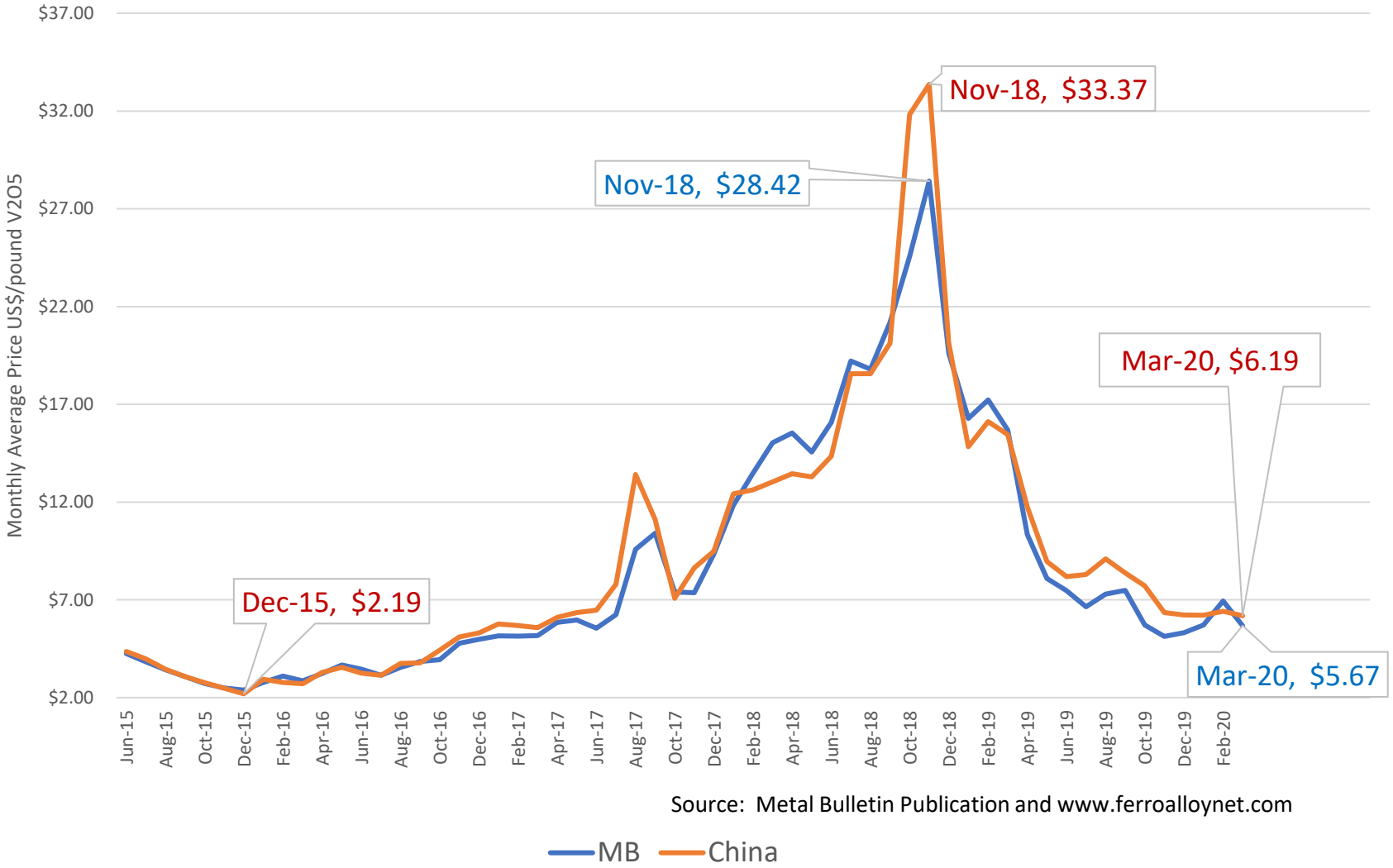
China V2O5 Monthly Price



Source: www.ferroalloynet.com

V2O5 Published Prices
Metal Bulletin Vs China

Monthly average published prices for V2O5



Source: Metal Bulletin Publication and www.ferroalloynet.com