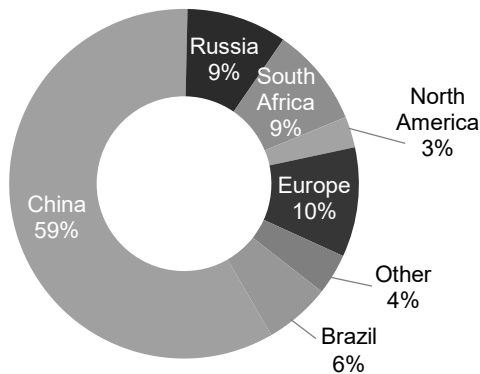
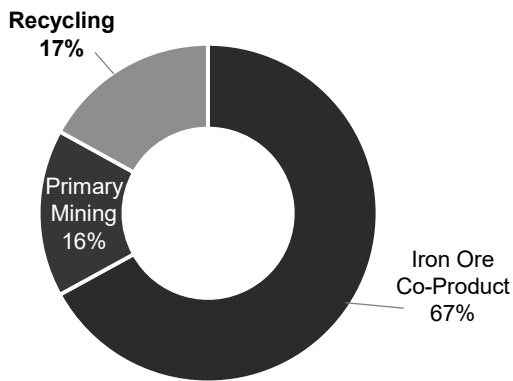


# WHAT IS VANADIUM?

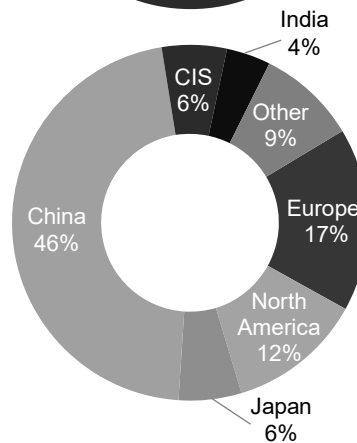
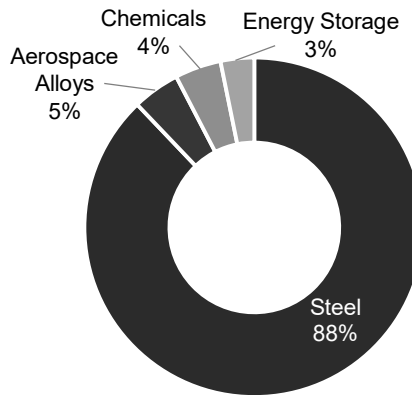
## Vanadium Production

Total 2018 Production = ~89k MT



## Vanadium Consumption

Total 2018 Consumption = ~97k MT



## HOW IS VANADIUM PRODUCED?

- Vanadium is present in the Earth's crust and is produced either from processing iron ore or crude oil
- Vanadium coming from iron ore is either the result of steel co-production, or primary mining
- Vanadium coming from crude oil is either extracted using catalyst or from processing the residue of burning/ gasification of heavy oil for power generation



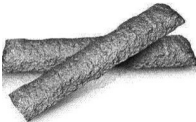
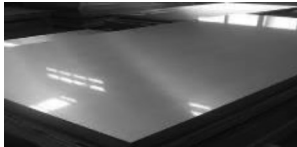

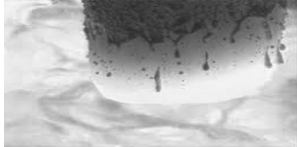


## WHAT IS VANADIUM USED FOR?

- The predominant use of vanadium is as a microalloy for the production of high strength steels (e.g. rebar) and tool steels
- In the aerospace sector, vanadium ensures low density, high strength and resiliency to high operating temperatures
- Vanadium redox flow batteries (VRFBs) require liquid vanadium electrolyte to store energy

Source: TTP Squared Inc., AMG analysis

## AMG VANADIUM PRODUCTS

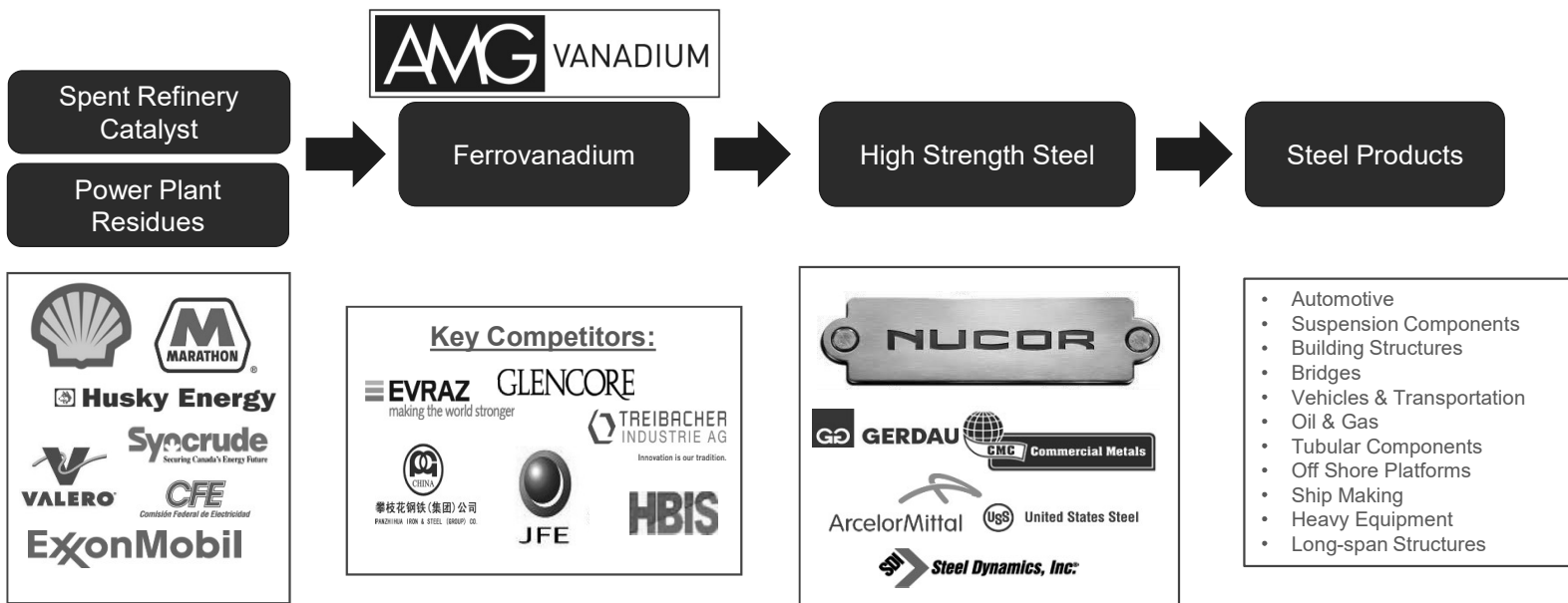
- The majority of profitability is associated with Ferrovandium and Ferronickel-molybdenum
- The sale of Revan™ and LimeAdd™ allow AMG Vanadium to avoid landfilling costs

PRODUCTS	VALUE PROPOSITION	APPLICATIONS
 <p data-bbox="289 930 488 995">Ferovan® (Ferrovandium)</p>	<ul style="list-style-type: none"> <li>• High strength low alloy (HSLA) steel used for construction, shipbuilding, pipeline, bridges, energy, automotive, etc.</li> <li>• Rail steels, tool and die steels</li> <li>• Rebar</li> </ul>	
 <p data-bbox="289 1098 451 1192">FeNiMoly® (Ferronickel-molybdenum)</p>	<p data-bbox="597 1119 1211 1178">Alloy addition for stainless steel and NiMo low-alloy steels</p>	
 <p data-bbox="289 1266 532 1331">Revan™ (Calcium Aluminate)</p>	<p data-bbox="597 1272 1044 1304">Slag-conditioner for the steel industry</p>	
 <p data-bbox="289 1419 496 1484">LimeAdd™ (Calcium Sulfate)</p>	<p data-bbox="597 1440 1143 1472">Solidification and stabilization of drilling waste</p>	

99% of the hazardous waste that AMG Vanadium receives is converted into salable product

## AMG SPENT CATALYST VALUE CHAIN – A “CRADLE-TO-GRAVE” SOLUTION

- AMG Vanadium processes spent catalyst in a roasting facility in order to remove the sulfur
- The roasted catalyst is then melted in an electric arc furnace (EAF) where the Ferronickel-molybdenum is extracted
- The molten material is passed to a second EAF furnace where the ferrovanadium is extracted
- The Ferrovanadium is sold to domestic steel producers



AMG Vanadium is the largest processor of spent catalyst in North America

## SPENT CATALYST CONTRACT STRUCTURE



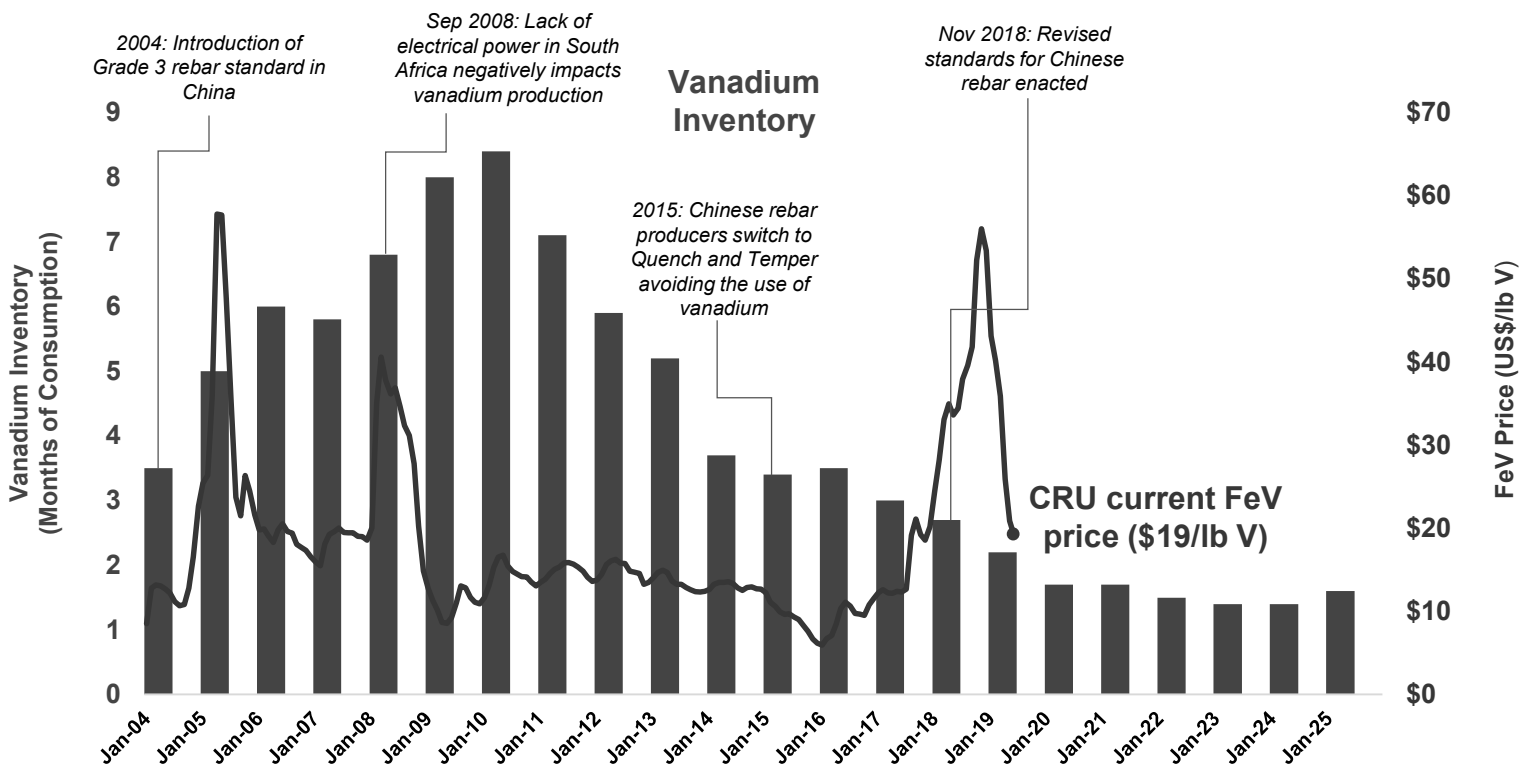
- Because of the income the refineries receive from the sale of finished products, utilizing AMG is the cheapest and most environmentally-sound way to dispose of their hazardous spent catalyst waste
- The tipping fee AMG Vanadium receives makes its operation significantly lower cost than primary mining
- AMG Vanadium and Cambridge II are profitable at all ferrovanadium prices

AMG Vanadium business model ensures long-term profitability

## VANADIUM MARKET DYNAMICS – SUPPLY AND DEMAND DRIVERS

Demand		Supply		
STEEL	CHINESE REBAR STANDARD	CHINA	FACILITY CLOSURES	BARRIERS TO ENTRY
<ul style="list-style-type: none"> <li>• Steel production accounted for 88% of vanadium consumption in 2017</li> <li>• Use of vanadium in steel continues to rise with market share of high strength steel</li> <li>• Modernization of developing countries will only further increase the demand for high strength steel</li> </ul>	<ul style="list-style-type: none"> <li>• The Grade 3 rebar standard in China went into effect in late 2018 and compliance will necessitate the use of an additional 20,000 MT of vanadium in 2021, compared to 2018</li> </ul>	<ul style="list-style-type: none"> <li>• Beginning in 2017, China banned imports of vanadium slag, reducing Chinese feedstocks by 3,000 MT</li> <li>• Chinese environmental regulators have refused to issue permits for stone coal operations, eliminating further potential vanadium production of ~3,000 MT</li> <li>• A gradual shift away from blast furnaces (BOF) to electric arc furnaces (EAF) as the Chinese domestic scrap supply grows has also reduced vanadium production</li> </ul>	<ul style="list-style-type: none"> <li>• During 2015/16, South African producers Evraz Highveld and Vanchem were liquidated, reducing global production by 11,000 MT (~13%)</li> <li>• China forced the closure of several high-cost, low-quality domestic iron ore mines resulting in increased imports of non vanadium-containing iron ore</li> <li>• Gulf Chemical, a large spent catalyst processor in North America, declared bankruptcy and shut operations in 2016</li> </ul>	<ul style="list-style-type: none"> <li>• There are no new vanadium projects under construction. Once undertaken, new projects typically require 3-5 years to have an impact on supply</li> <li>• Financing for greenfield projects is challenging due to significant capex (\$300M+) and a lack of understanding of vanadium by capital markets</li> <li>• Mining projects contain significant downside pricing risk while recycling operations (e.g., AMG-V) rely on complex technology</li> </ul>

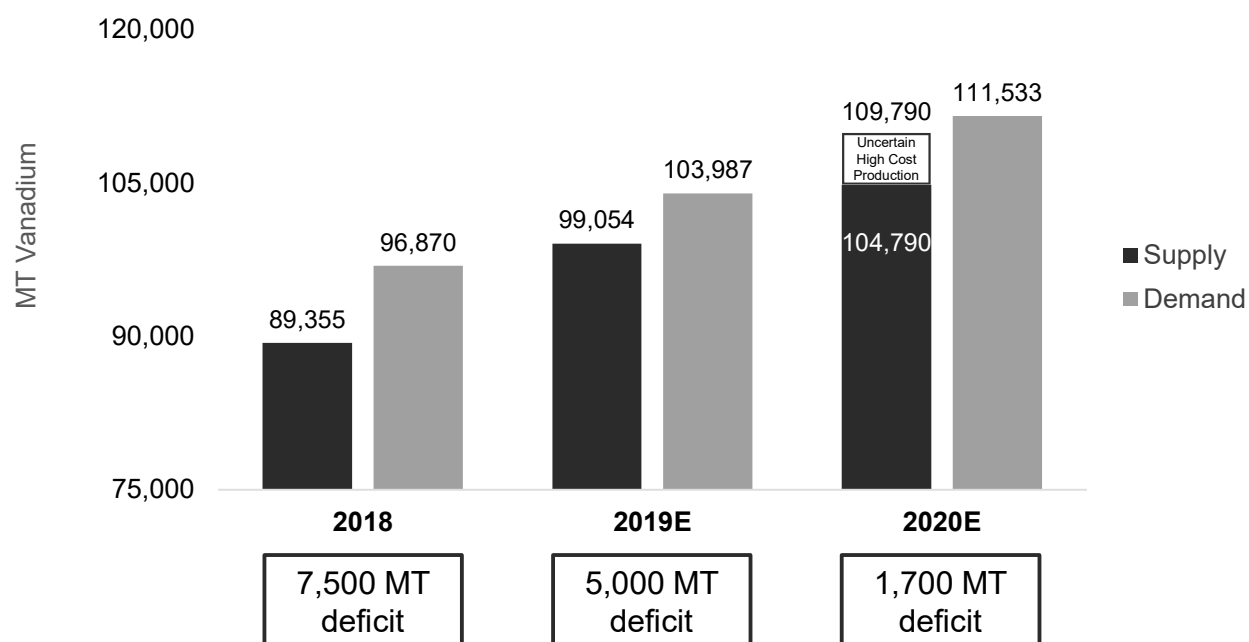
# VANADIUM: INVENTORY VS. FEV PRICE



Slight under-supply position is forecasted to continue for the next several years, driving down global inventories to near-record lows

Sources: - Fe-V price: CRU Ryan's Notes – average monthly US FeV 80% V Mid  
 - Inventory: TTP Squared Inc.

## PROJECTED VANADIUM SUPPLY DEFICIT



Ongoing market deficit expected for the next several years, continuing drawdown in global inventories