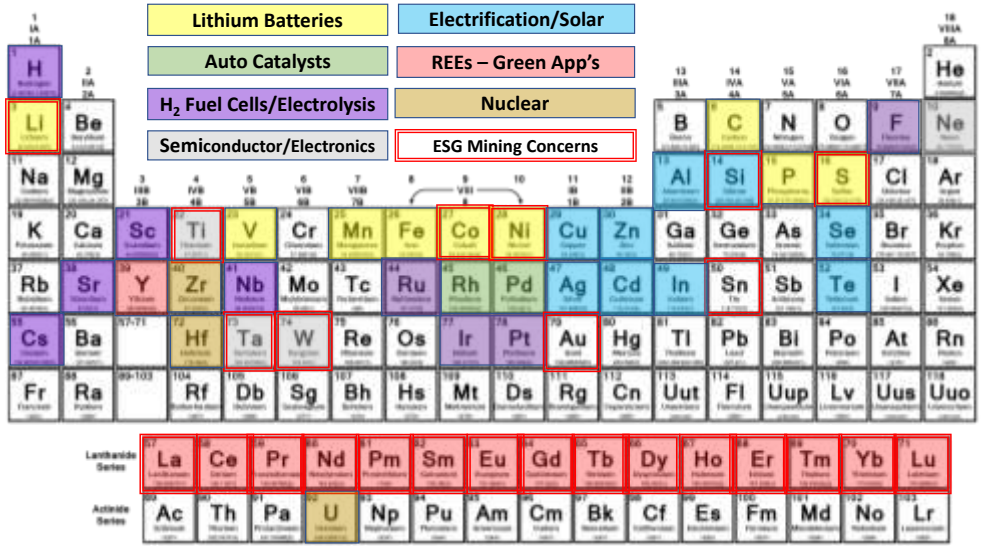
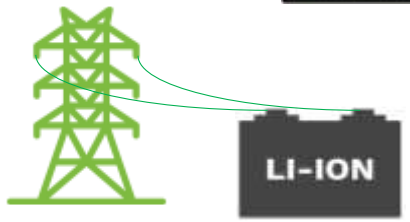
NEDBANK

Periodic Table of the Elements

Lithium Batteries | Electrification/Solar
Auto Catalysts | REEs – Green App's
H_2 Fuel Cells/Electrolysis | Nuclear
Semiconductor/Electronics | ESG Mining Concerns

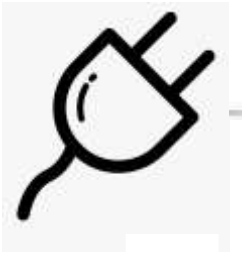




The Future of PGM's

Presented at the Nedbank Hydrogen and Fuel Cell Roundtable
November 6, 2024

Presented by
Matt Watson, Precious Metals Commodity Management LLC

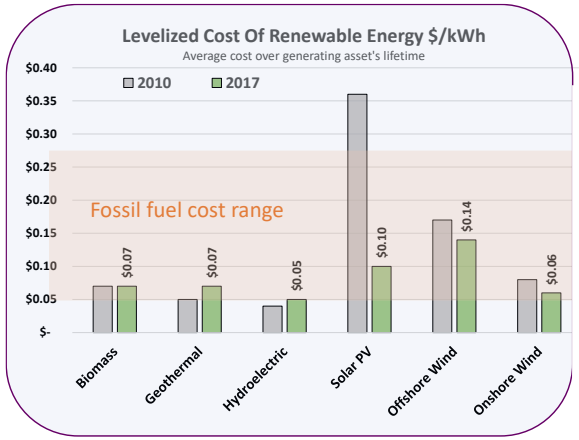


The Clean Energy Transition Roadmap

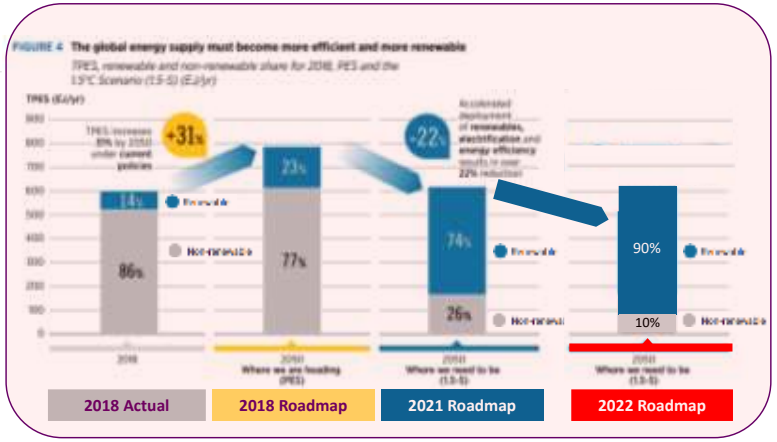
Roadmap is not attached to mineral requirements

Clean Energy Transition - Macro Level

- **Macro Trend #1: Renewables getting cheaper**
  - IRENA Moved Renewable 2050 goal posts profoundly
- **Macro-Trend #2: The Electrification of Everything**
- **The Big Disconnect:** Critical Mineral Mining Demands and Mining Development Timelines
  - Periodic Tables greatest strain is forecast on Copper, Silver, Uranium, Hf Zr, REEs (responsible REE mining ramp, REE's not a Known Reserves problem) and LiB metals.
  - Today's big critical mineral expansion plan is an inflationary plan.
- **Critical Minerals:** PGM's are now deemed critical, but not silver.
- **Global Emissions Control Failure In Progress:**
  - Global emissions will continue to climb. Period.
  - Western countries bending their emissions curve, but so what.
  - Emissions are following Asian GDP growth in route to a 10.1 billion global population.
  - Asia emissions and coal consumption are key.



Levelized Cost of Energy (LCE) calculations do not account for intermittent renewables. Actual costs proving higher in regions with higher variable renewable penetration rates.



Source: IRENA https://www.irena.org/
and World Energy Transitions Outlook: 1.5OC Pathway (irena.org)
and World Energy Transitions Outlook 1-5C Pathway 2022 edition (irena.org)

Supply Chain Disconnect
End Consumer Demand Vs. Mine Supply

Regulators and manufacturers are way ahead of mining and the front end of the supply chain.

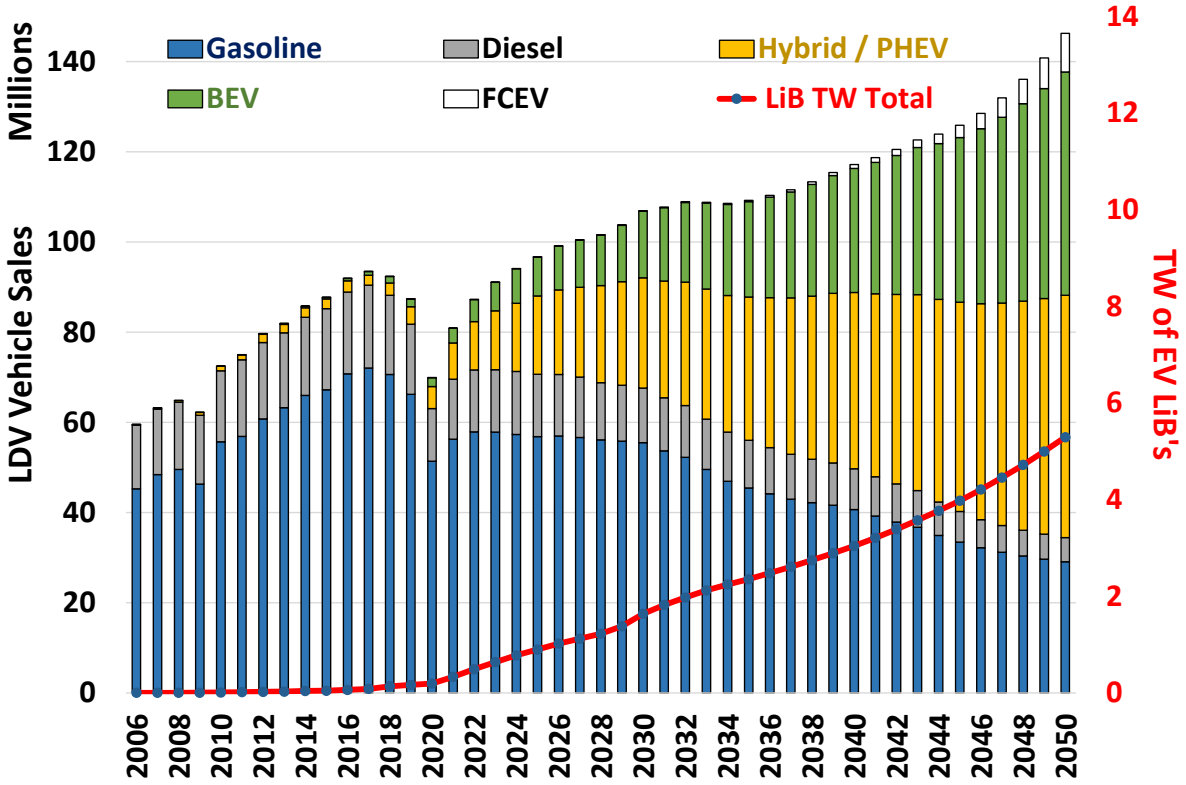
Mining Investment Market Shift:
- In the past 3y years, we have seen Tesla, VW, Ford, GM and others shifting investment into mining & mineral (intermediate) processing.
- Trend is towards Vertical Integration moving towards buying your own mines, but how much capital do they have vs. need? Not enough!

Coming Soon:  Global Power Grid
2x today with increased loadings of Cu, Steel, and Al

Critical Metals: Base Case Vs. High Case Long-Term Demand

	Base Case Demand	High Case Demand
EV/Powertrain Mix	Base Case Powertrain Mix Achievable with focused investment	Zero Emission Vehicle Mandates Likely not achievable with ESG timelines
Energy Storage LiB	50% of IRENA Goal (2.2TW)	100% of IRENA Goal (4.4TW)
Solar PV	100% of IRENA Roadmap Goal (14TW) Updated from 7 TW to 14 TW	100% of IRENA Roadmap Goal (28TW) Updated from 14 TW to 28 TW
Wind	50% of IRENA Roadmap Goal (4TW)	100% of IRENA Roadmap Goal (8.1TW)
Fuel Cell Vehicles	9M/year (5.5% of 2050 mix)	18M/year (11% of 2050 mix)
Clean H_2 / Electrolyzers	50% of H_2 Council Goal (300 GW) (75 GW PEM)	100% of H_2 Council Goal (600 GW) (150 GW PEM)
Ammonia	2x Today's Market by 2050	6X Today's Market by 2050
Nuclear	~1,850 add'l reactors by 2050 ($14T) (25% baseline of a 3x larger grid)	~2,650 reactors by 2050 ($22T) (25% baseline of a 4x larger grid)

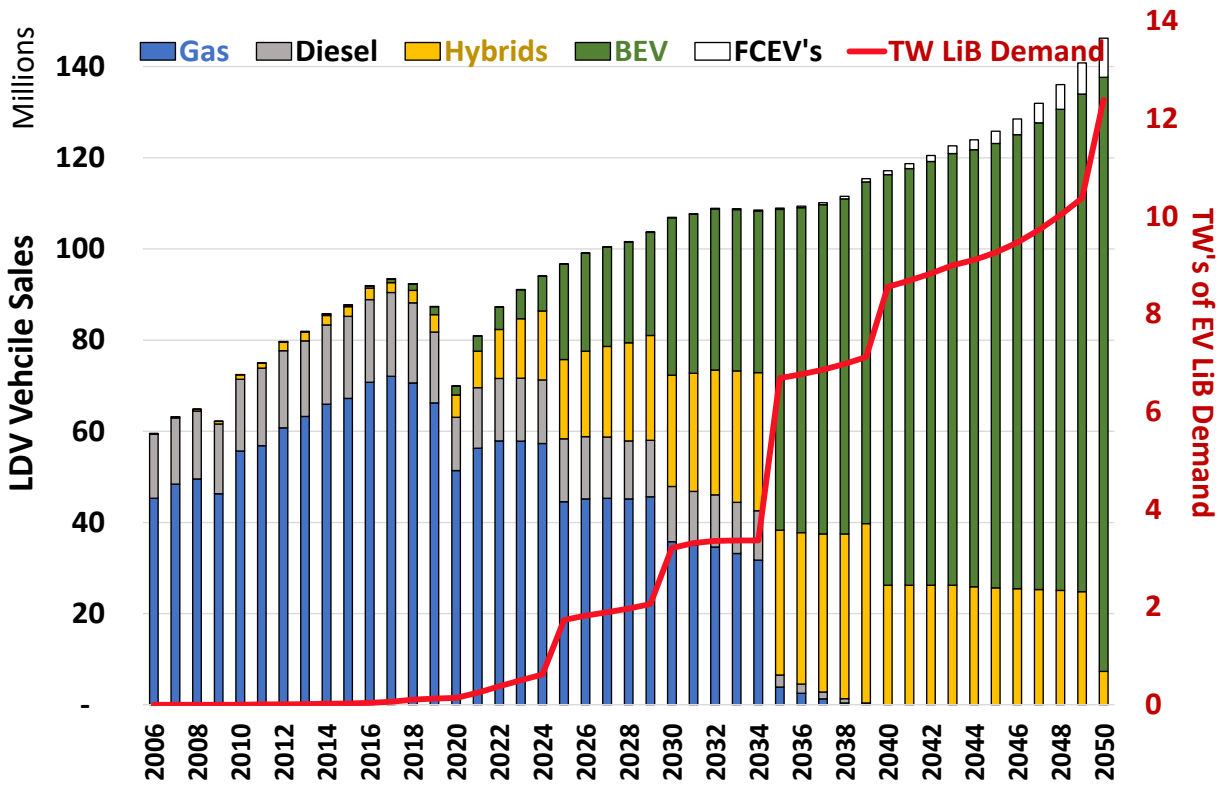
Projected Light Duty Vehicle Powertrain Mix



2050 Powertrain Mix

- FCEV 8.5M or 5.5% Mix
- BEV 50M or 37% Mix
- Hybrid + PHEV 64.5M or 41% Mix
- Diesel 5.4M or 3.4% Mix
- Gasoline 29M or 18% Mix

Base Case



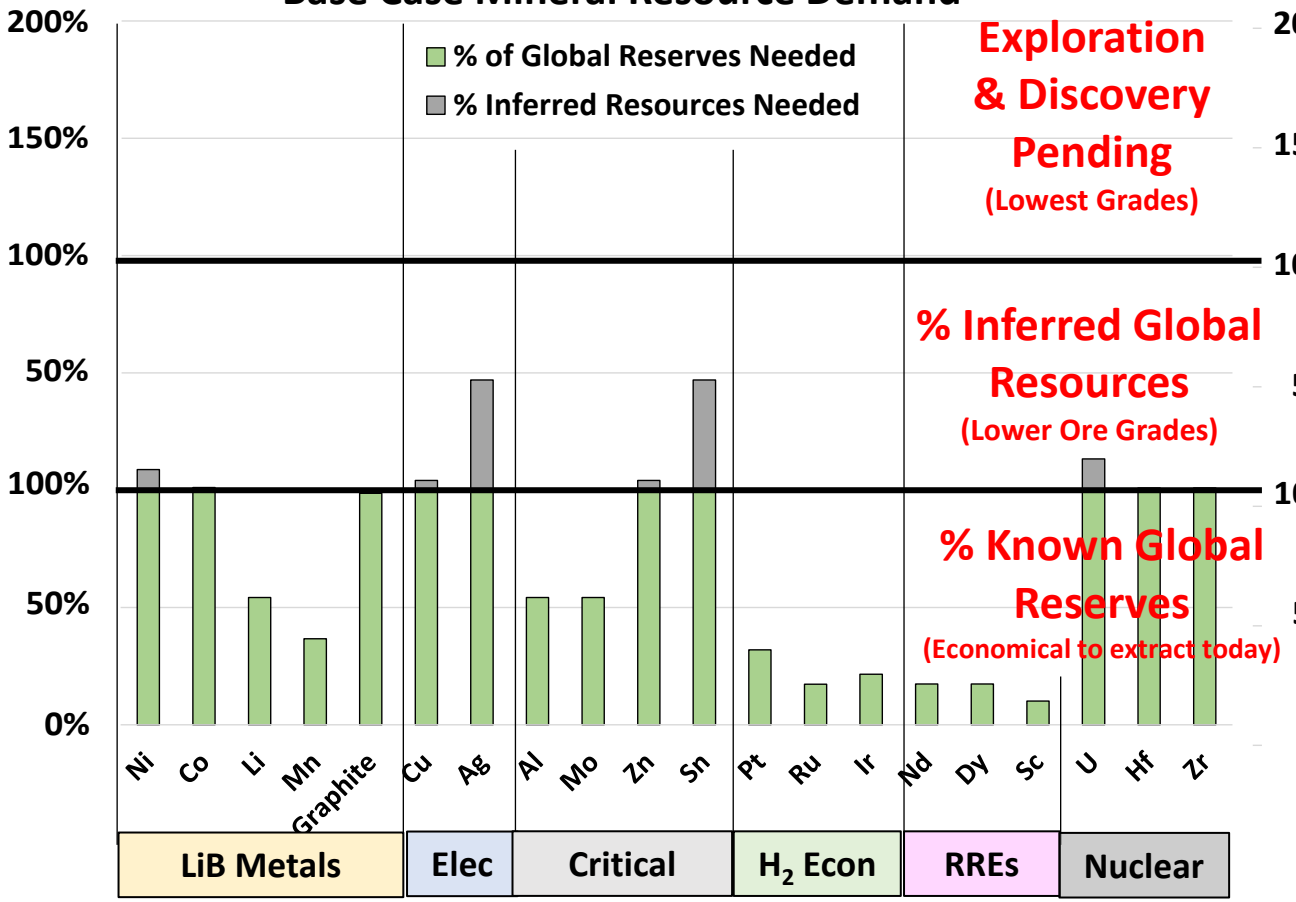
2050 Powertrain Mix

- FCEV 8.5M or 5.5% Mix
- BEV 130M or 83% Mix
- Hybrid + PHEV 18.1M or 11.5% Mix

Zero Emission Mandates Case

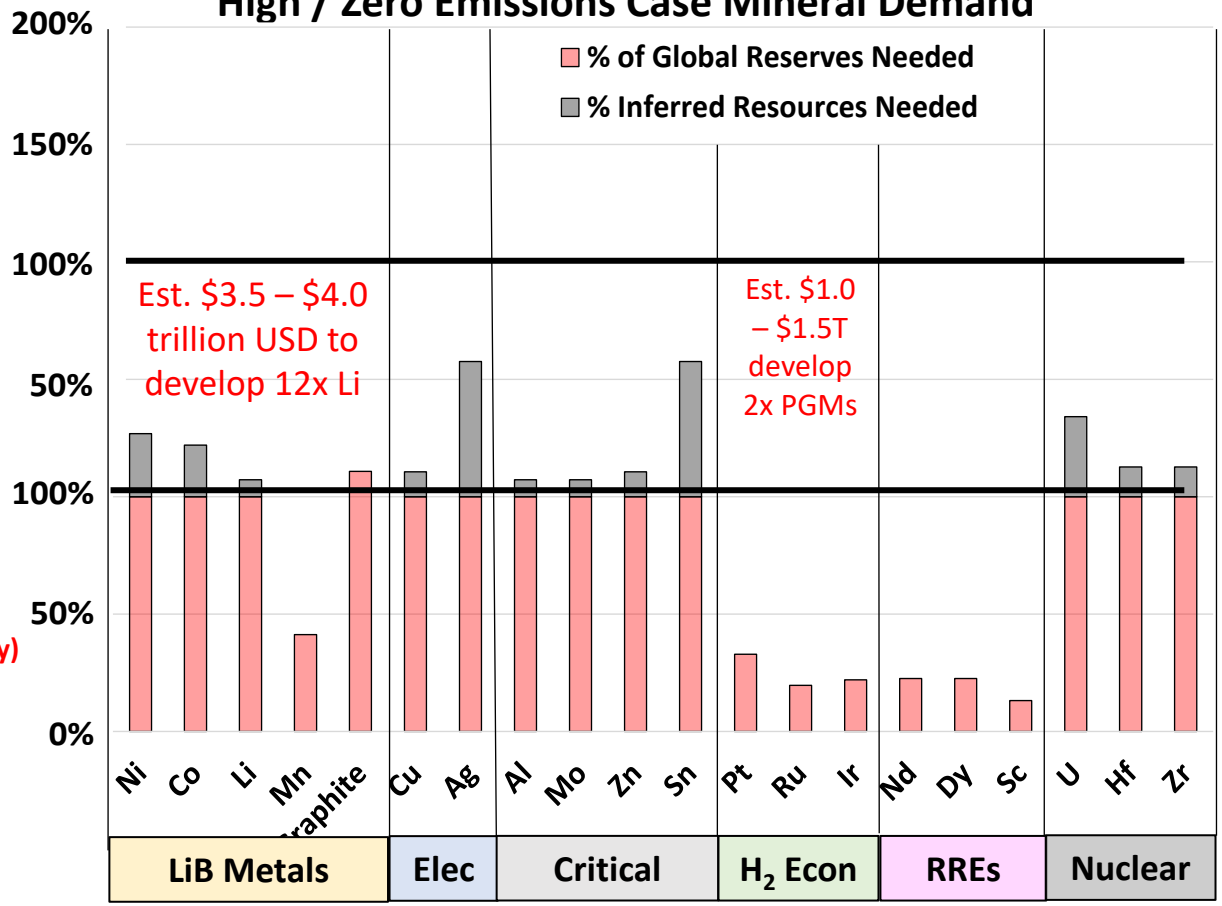
Critical Mineral Resource Requirements 2021 thru 2050 - Extended

Base Case Mineral Resource Demand



Base Case: Base Case Powertrain + 50% IRENA Renewables + 50% H_2 Council FCEV's & Green H_2

High / Zero Emissions Case Mineral Demand



High Case: Zero Emission Powertrain + 100% IRENA Renewables + H_2 Council FCEV's & Green H_2

Mining Versus the Environment is a Challenge

This is why a market analyst with a 30-year view is needed, because mining timelines have grown so long.

Exploitation of mineral resources gives rise to a variety of environmental and social implications that must be carefully managed to ensure reliable supplies

International Energy Agency

Selected environmental and social challenges related to energy transition minerals

Areas of risks		Description
Environment	Climate change	• With higher greenhouse gas emission intensities than bulk metals, production of energy transition minerals can be a significant source of emissions as demand rises • Changing patterns of demand and types of resource targeted for development pose upward pressure
	Land use	• Mining brings major changes in land cover that can have adverse impacts on biodiversity • Changes in land use can result in the displacement of communities and the loss of habitats that are home to endangered species
	Water management	• Mining and mineral processing require large volumes of water for their operations and pose contamination risks through acid mine drainage, wastewater discharge and the disposal of tailings • Water scarcity is a major barrier to the development of mineral resources: around half of global lithium and copper production are concentrated in areas of high water stress
	Waste	• Declining ore quality can lead to a major increase in mining waste (e.g. tailings, waste rocks); tailings dam failure can cause large-scale environmental disasters (e.g. Brumadinho dam collapse in Brazil) • Mining and mineral processing generate hazardous waste (e.g. heavy metals, radioactive material)
Social	Governance	• Mineral revenues in resource-rich countries have not always been used to support economic and industrial growth and are ofte • Corruption and brib
	Health and safety	• Workers face poor chemicals) • Workers at artisana access to safety ec
	Human rights	• Mineral exploitation (e.g. children have • Changes in the cor

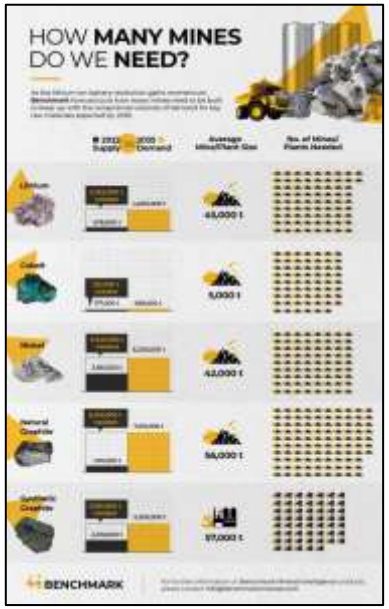
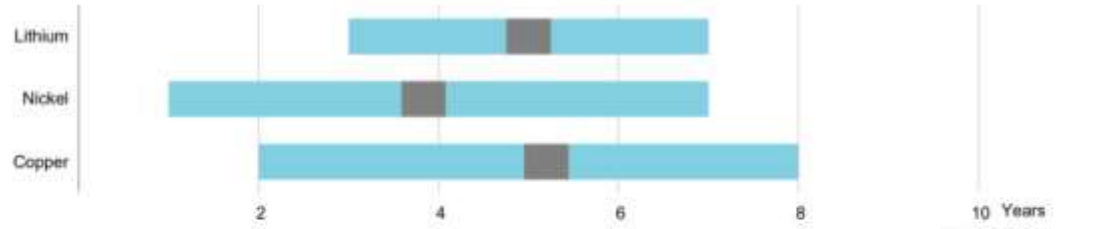


Figure 1.15 Lead times for mining of selected minerals

International Energy Agency

Global average, 2010-2019

Average observed lead time for selected minerals (from feasibility to production)



IEA. CC BY 4.0.

Note: Lead time averages are based on the top 35 mining projects that came online between 2010 and 2019.

Sources: IEA analysis based on S&P Global (2020); S&P Global (2019); Fraser et al. (2021); Heijlen et al. (2021).

Exploration takes the most time in bringing new mines into operation, while construction and ramping up production to full capacity typically take almost a decade.

Energy Technology Perspectives 2023 (windows.net)

ICE & Auto PGM Market

ICE LDV sales slump post COVID

WLPT/RDE & Tighter Emission Standards Loading Impact

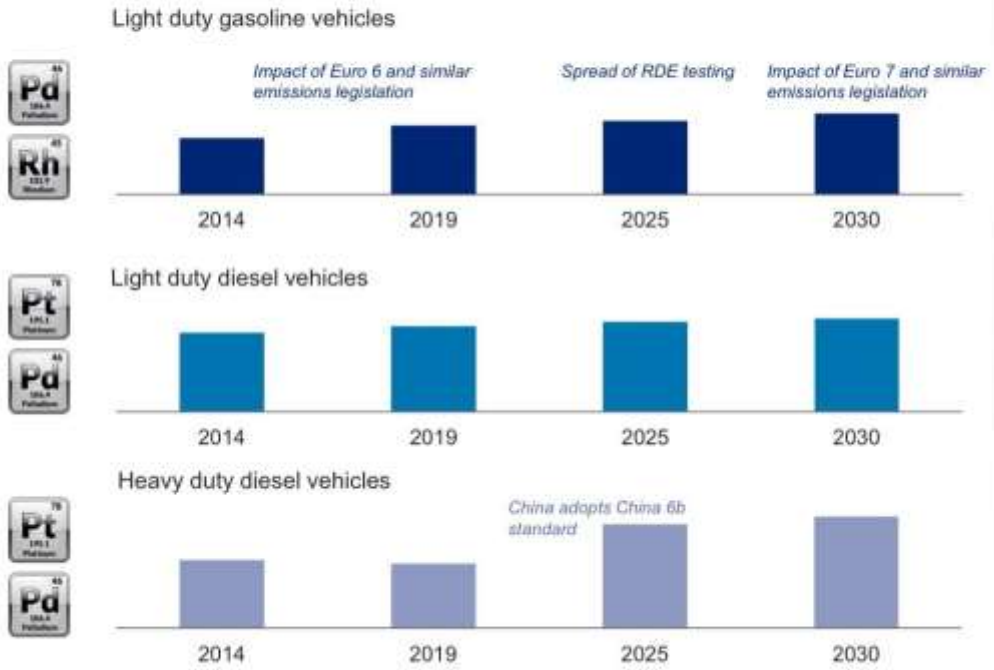
ANGLO AMERICAN

Also: Hybrid & PHEV loadings are +5% to +10%

Loadings higher than ICE. Frequent cold starts create emissions transients requiring PGM's to countermeasure to meet WLPT/RDE test requirements.

AUTO PGM DEMAND SUPPORTED BY HIGHER LOADINGS

Typical historic and forecast 3E light duty PGM loadings[15]



LDV Gas PGM loadings: Pd:Pt:Rh

~17%

between 2019 and 2030 due to tighter emissions legislation in China and Europe

LDV Diesel PGM loadings: Pt:Pd:Rh

~10%

between 2019 and 2030 from already high levels

HDV Diesel PGM loadings: Pt:Pd

~60%

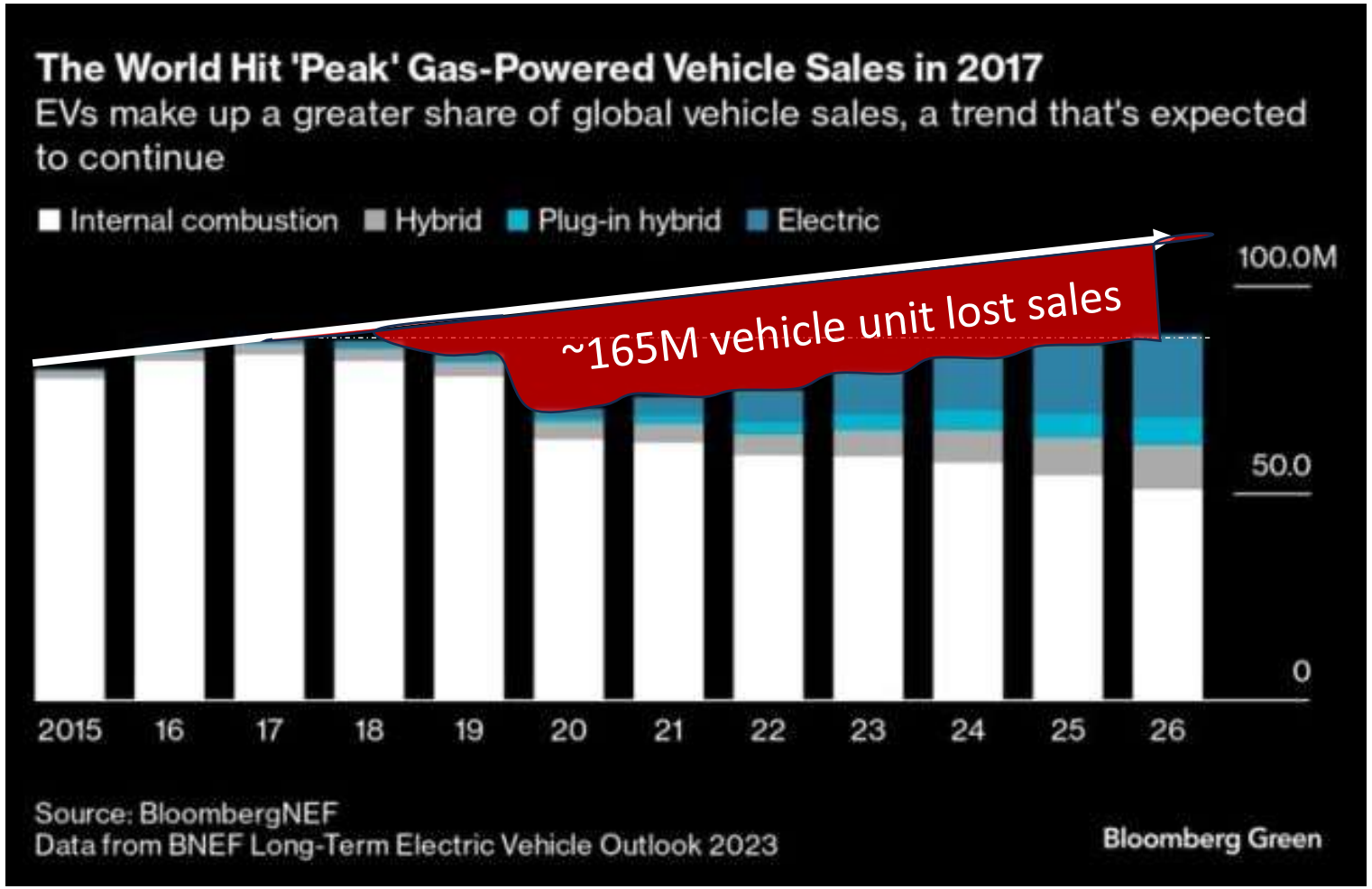
between 2019 and 2025 as China and India adopt tougher emissions standards

LDV Vehicles Sales: Bloomberg's View

Post Pandemic LDV vehicle sales volumes (all powertrains) … collapse >20%.

2026: Hope to once again match those 2017 sales again by 2026. Decade long slump

Losing 2-years worth of auto demand in the course of 1 decade.



2023 Global Gas-Powered Vehicle Sales Have Fallen 23% Since 2017 Peak

Auto Catalyst PGM's – Market Price Trend & Outlook

Platinum Prices for the Last 5 Years

Palladium Prices for the Last 5 Years

Rhodium Prices for the Last 5 Years

Outlook

↑ Hydrogen Economy Demand ensures higher pricing long-term

- FCEV Pt Loading far greater than AutoCatalyst today.
- Diverse Pt demand – Chemical, Electrical, ElectroChem, Petrol, Glass Production, Medical, Auto, Advanced Pharma, etc.
- ICE Auto Catalyst Pt→Pd design swap nearing completion. Almost time to back to Pd for cost.

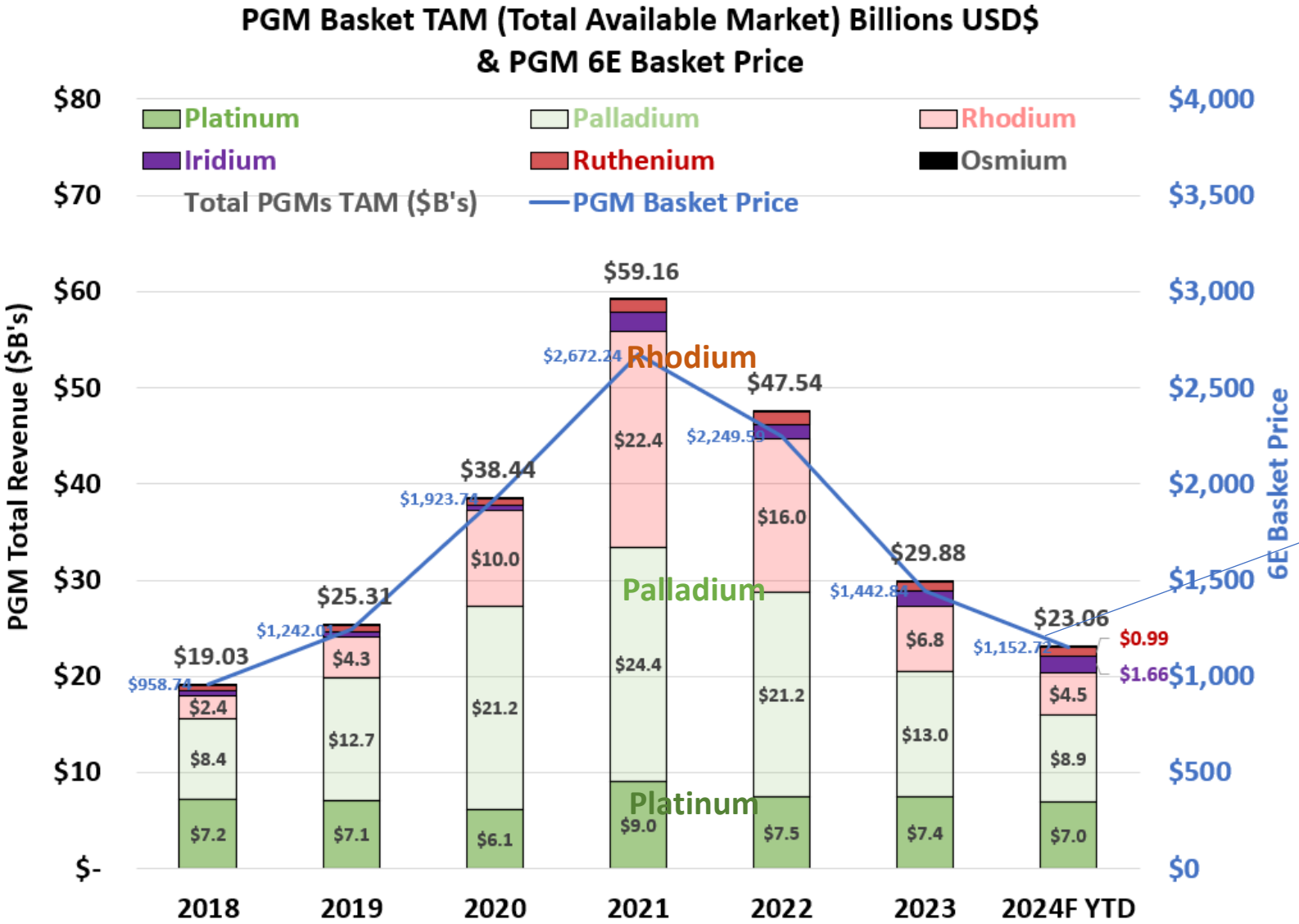
↓ Weak Auto Demand and growing surplus from expanding AutoCat recycle supply & Pd rich PGM mining

- Short-term: Post COVID car sales slump never fully recovered. Increased ICE sales would push short-term pricing higher.
- Long-term: Post 2030 significant surplus accumulation will drive price way down. Alternative Pd demands needed.

↓ Weak Auto Demand and growing surplus from expanding AutoCat recycle supply

- Short-term: Post COVID car sales slump never fully recovered. Increased ICE sales would push short-term pricing higher.
- Long-term: Post 2030 significant surplus accumulation will drive price down. More diverse Rh demand when Rh < $1,000

The Dramatic Rise and Fall in Palladium and Rhodium Basket Prices



TAM = Total Available Market Revenue

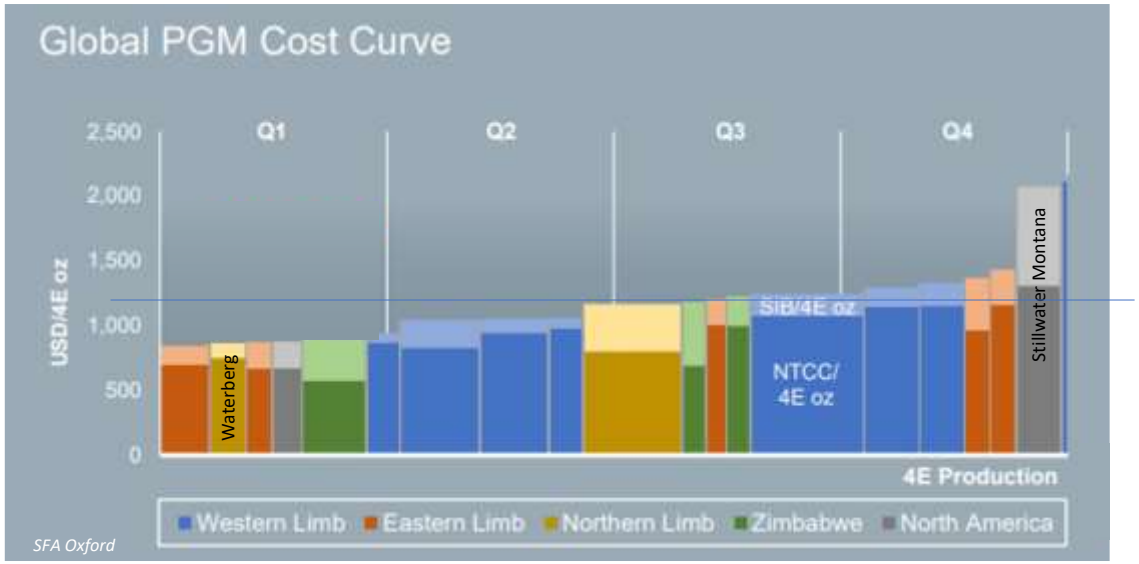
= Basket Ave Annual Price

- Total Supply Volume ($ Billions USD)

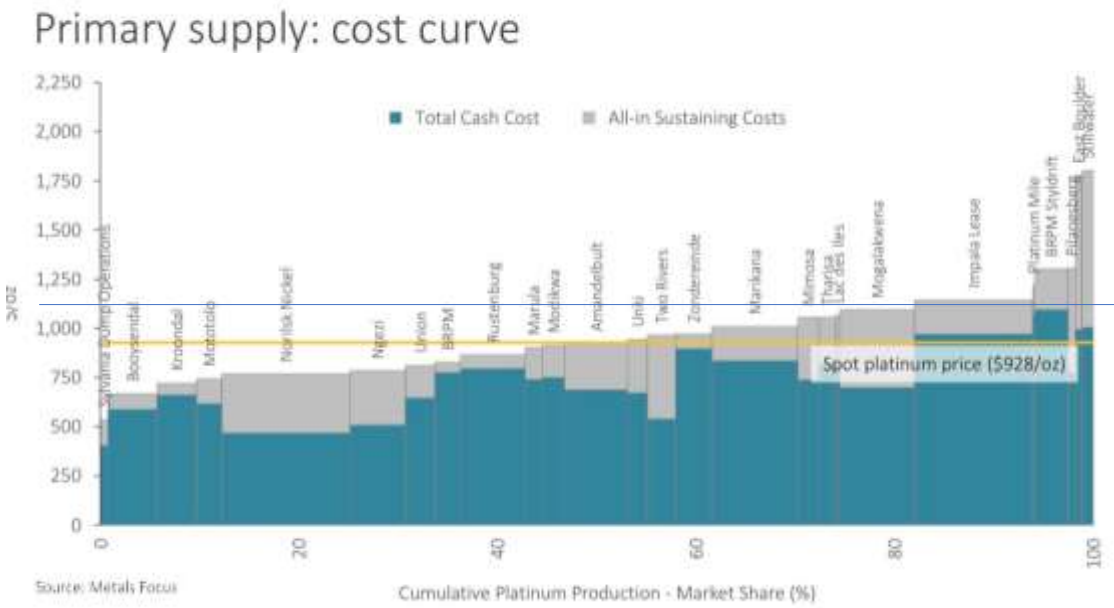
$1,152/Toz PGM 6E basket price.

The PGM Mining Industry: is slowly removing highest cost mines

45% to 50% PGM Mines Underwater in AISC



6E PGM
$1,152/toz

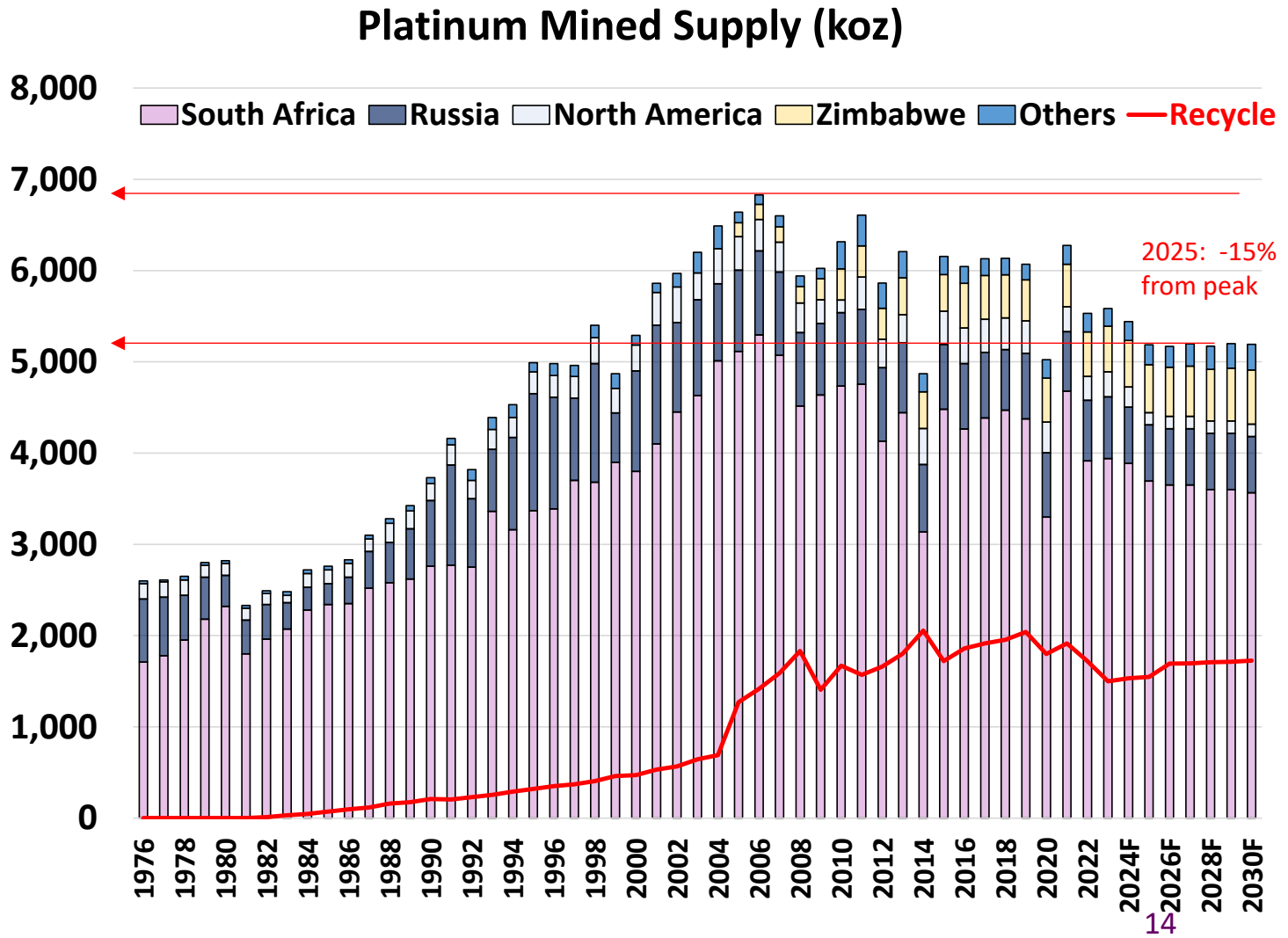


6E PGM
$1,152/to

Sibanye-Stillwater Montana Cutting Mine Production 50%

PGM Industry wide expect -8% mine supply in 2025

Two unidentified miners hand drill for ore at a Sibanye Stillwater Montana mine.

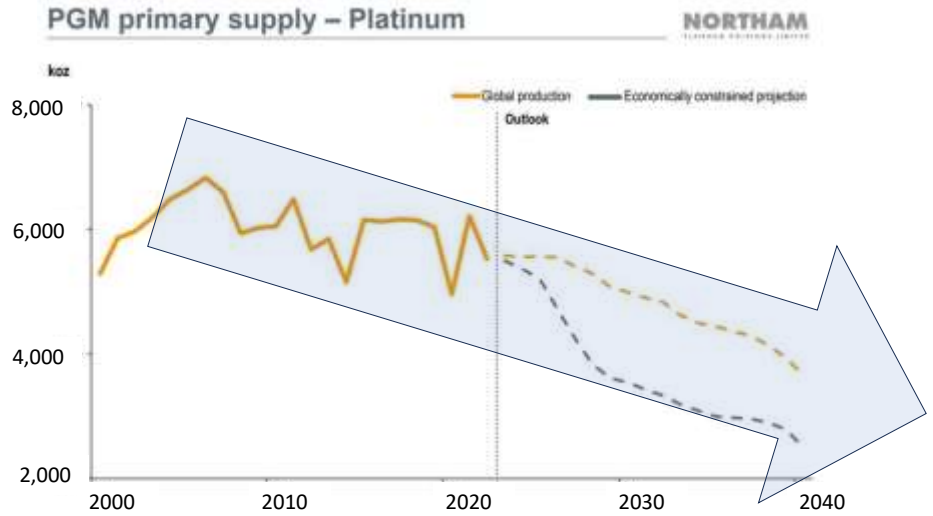


The Palladium & Rhodium Challenge

The PGM basket increasingly out of balance

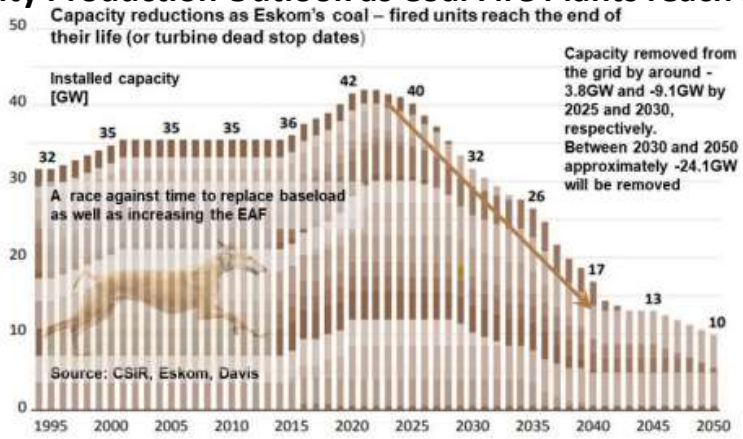
What PGM's Are We Mining?

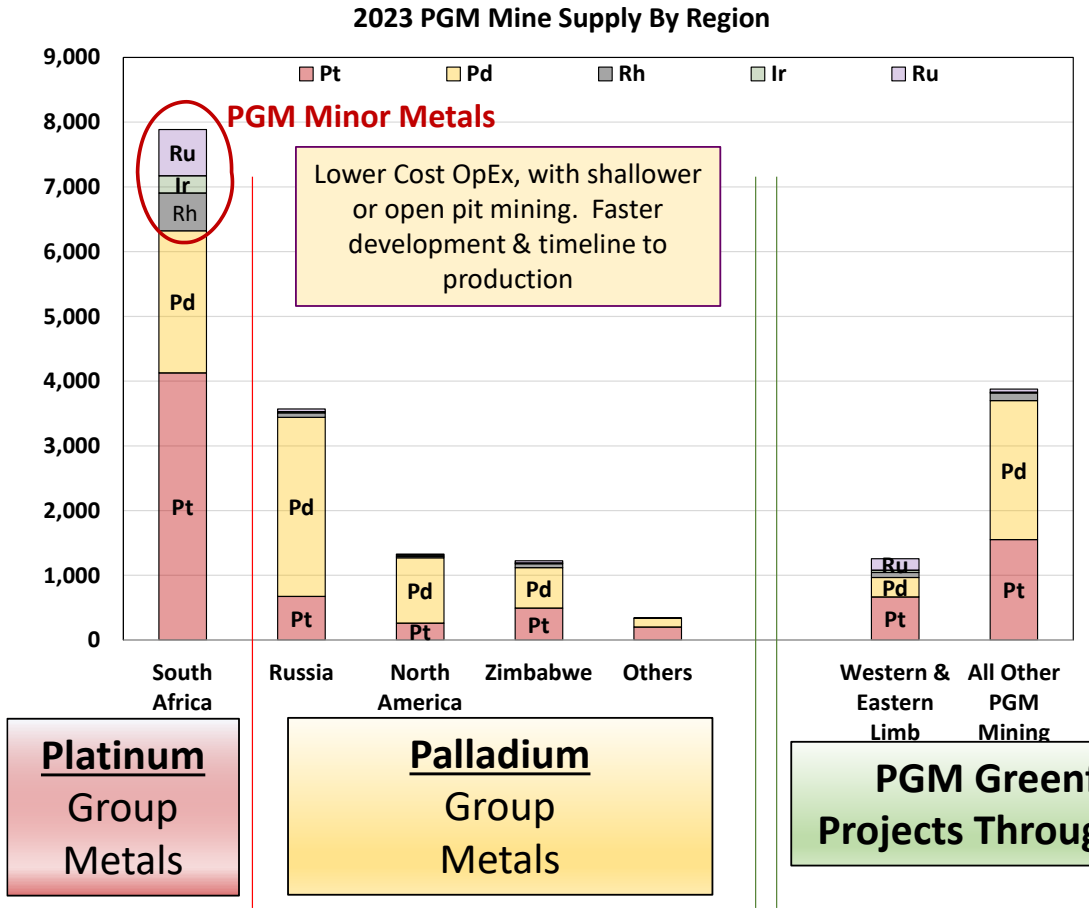
Platinum Group Metals - Versus - Palladium Group Metals



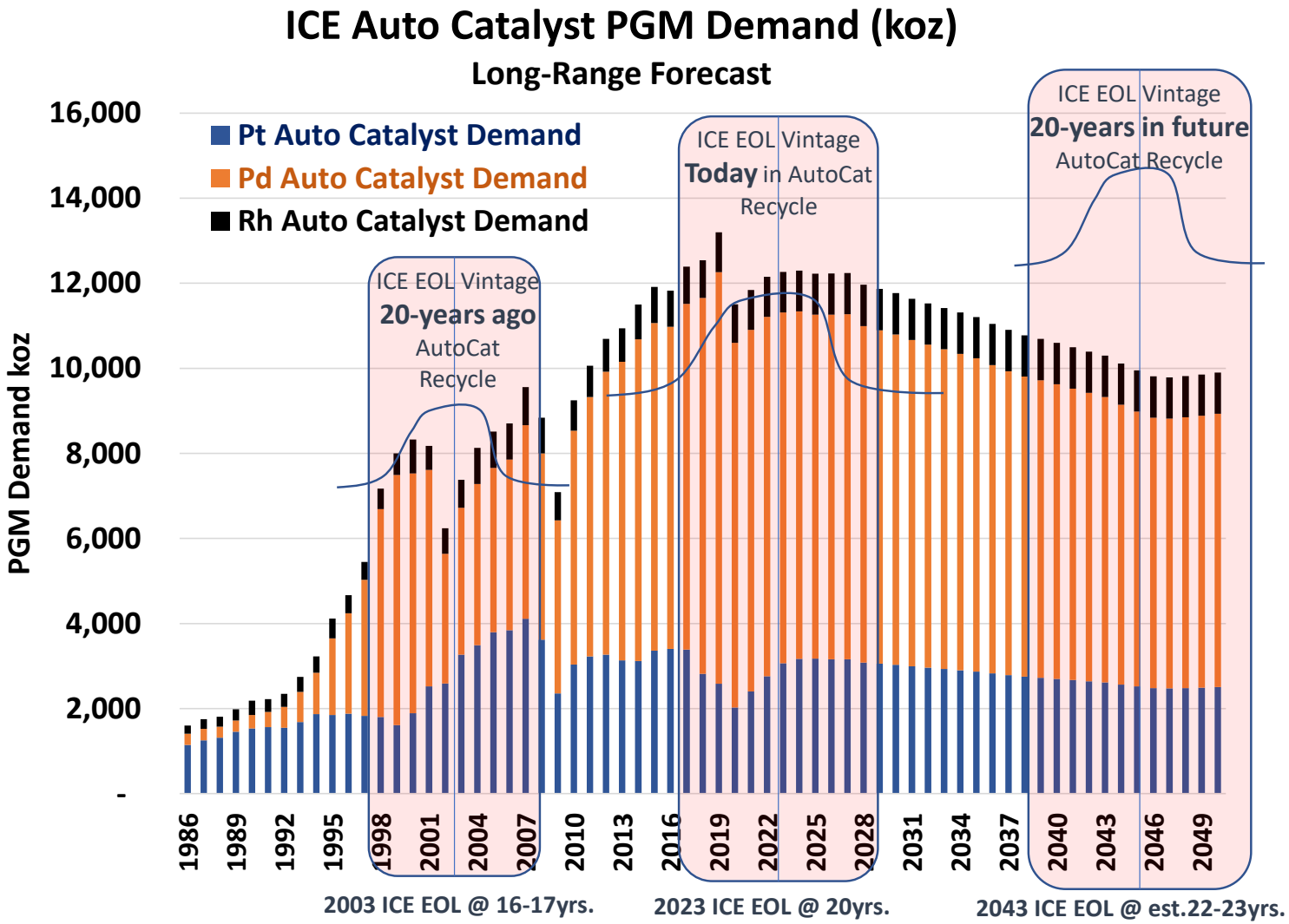
Dramatic S. African PGM Mine supply reductions coming our way, right when we need maximum H_2 Economy Support from Platinum + Iridium + Ruthenium.

Electricity Production Outlook as Coal Fire Plants reach EOL





2023: -35% Auto Catalyst Recycle Market: Are We Witnessing A Shifting ICE Age? Yes



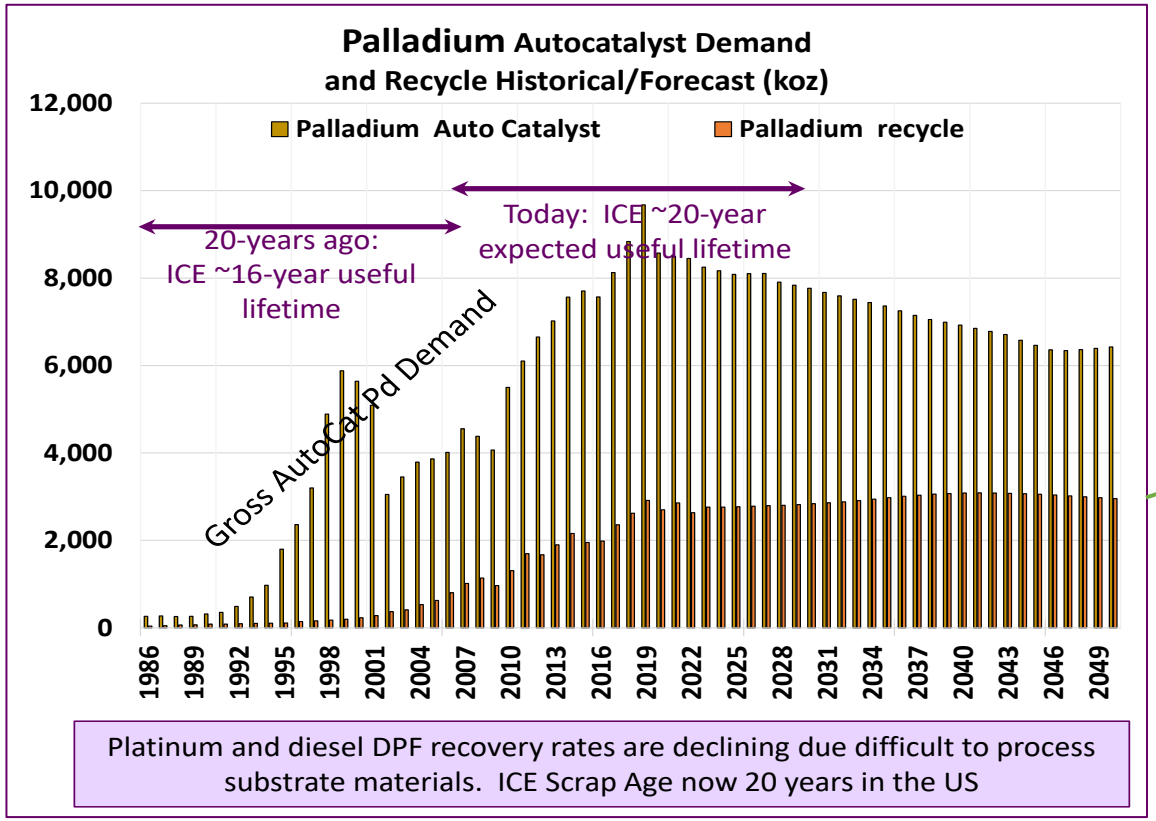
Message: Greater volume and higher mix of Pd coming back from 1.44 billion ICE on the road yet to go to scrap.

Updated Model
1. *Slower return rate*
2. *Macroeconomic slowdown*

Increasing Pd AutoCat Recycle Adds To Future Pd Oversupply

- Palladium pushing from structural deficit to structural surplus without new demand source(s).

Palladium Auto Catalyst Gross Demand vs Pd Recycle

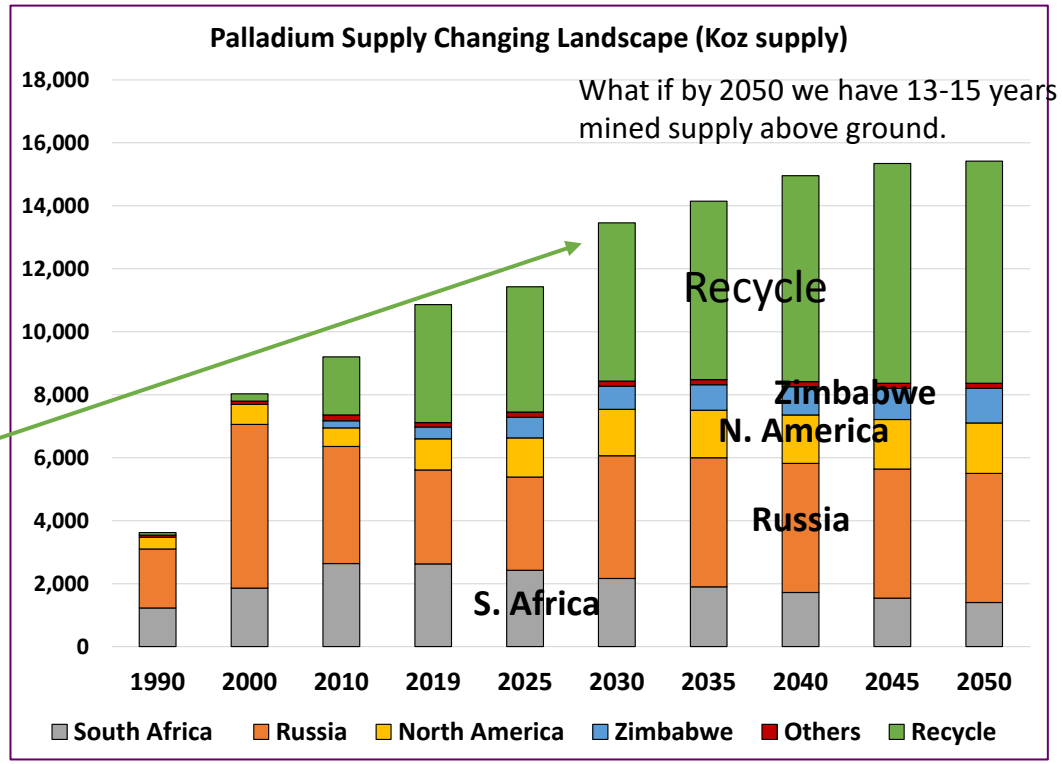


Platinum and diesel DPF recovery rates are declining due difficult to process substrate materials. ICE Scrap Age now 20 years in the US

Massive ICE Palladium Recycle Growth
- 1.44 billion gasoline and diesel LDV on the road today.
- ~3g ave. Pd recovery per vehicle
- 125 Moz AutoCat Pd Recycle by 2050

Base Case

Palladium Long-Term Supply Outlook



- Russian Pd miming will expand with additional Ni for LiBs
- Long-Term S. Africa PGM mining declines
- Zimbabwe PGM mining expansion
- N. America Pd byproduct mining should increase

PLATINUM GROUP METALS

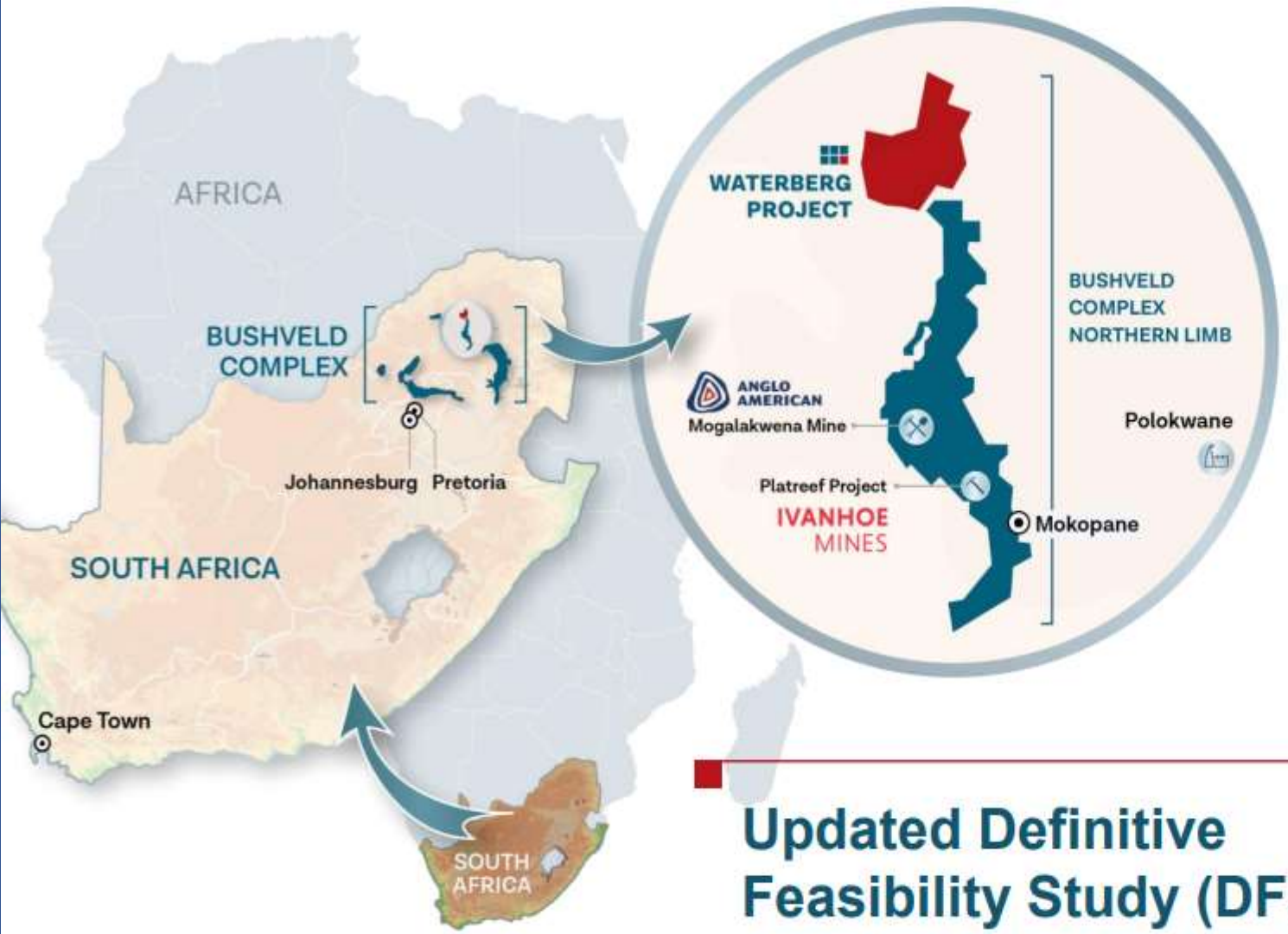
WATERBERG PGM

Large-scale, low-cost PGM mine development in South Africa

CORPORATE PRESENTATION

SEPTEMBER 2024

LOCATION AND BACKGROUND



Located on the North Limb of the Bushveld Complex; home to 70% of global platinum production in 2023

Discovered in 2011 with US$89M invested to date in exploration and feasibility engineering

Updated Definitive Feasibility Study (DFS) September 2024

Evaluating smelter offtake and funding options for project development

WHY **WATERBERG.**

PLATINUM GROUP METALS

Measured and Indicated Resource
33.76M ounces
Palladium, Platinum, Gold and Rhodium (4E)

THICK

Amenable to **bulk mechanized mining** – safe with higher skilled work force

UNIQUE

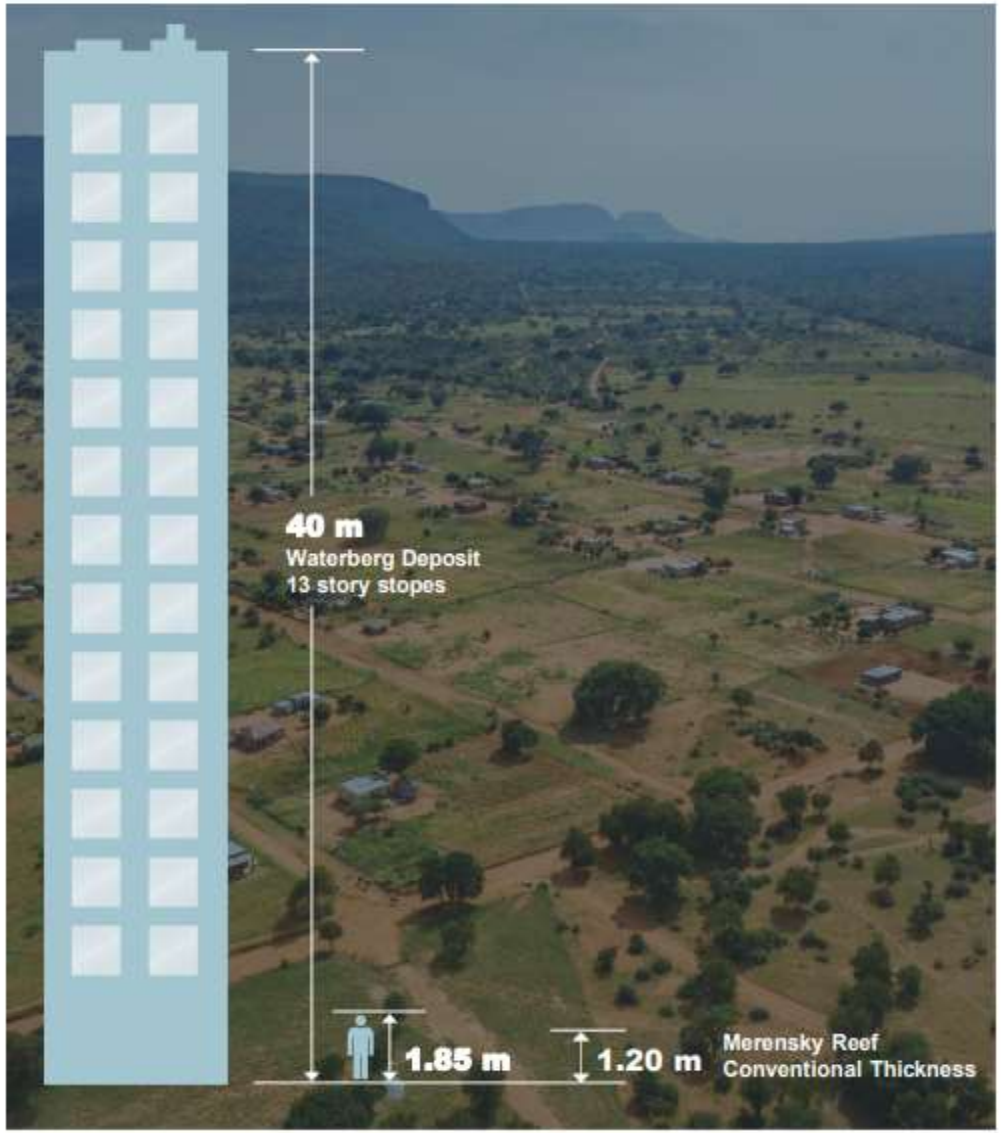
Full suite of PGMs including strong gold, nickel and copper credits.

SHALLOW

Deposit starts 140m from surface – allows for potential multi decline ramp access – **lower capital costs** compared to deep vertical shafts

DESIRABLE

Low chrome **concentrate** with **high-sulphide** content amenable to existing smelters



100% Waterberg Project. See Press Release dated September 16, 2024, and Appendix. www.sedarplus.ca

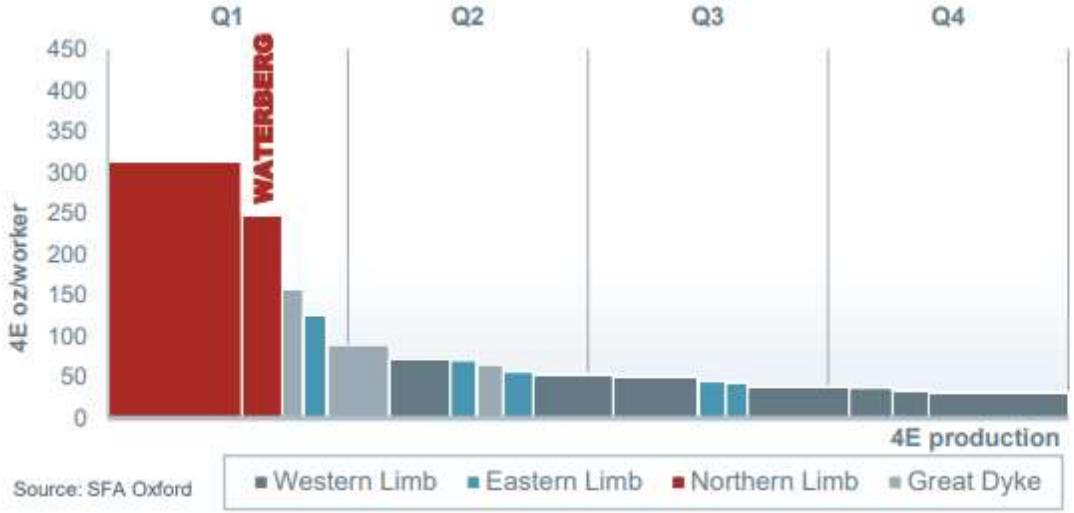
WATERBERG Advantage: Thickness, Depth, Productivity and Cost

PLATINUM GROUP METALS

PGM Orebody Thickness and Grade

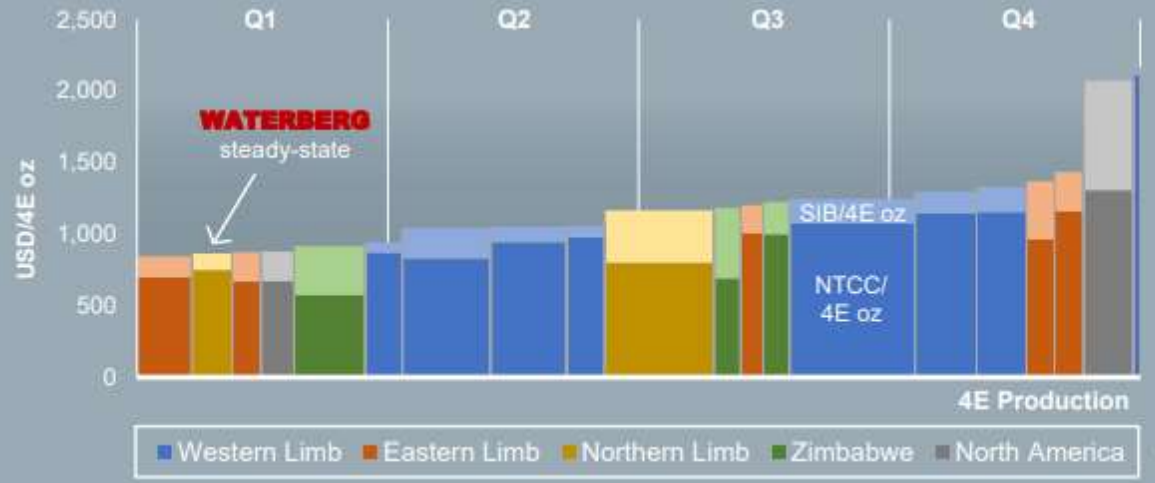
South African PGM Mine & Project Average Deposit Depths

4E oz Production Per Worker



Source: SFA Oxford

Global PGM Cost Curve



The Palladium Challenge: What Do We Do About Palladium?

PGM Industry Needs Palladium Market Stability

- **Technology: Too Few New Patents Using Palladium**
  - Norilsk studies all Nickel and Palladium based new Patents. They are worried limited new Pd technical developments and new patents.
  - Started the ($350k prize pool) Pd Challenge contest with the IPMI, but due to the Ukraine conflict, had to be put on hold.
  - Now Nornickel is taking up new initiatives with Russian academia to develop H_2 Economy related Pd demand.

NORNICKEL

- **Palladium Applications for Clean Energy**
  - 80+% of Palladium demand in past few decades was in ICE Auto Catalyst.
  - Long Term AutoCat Recycle requires near doubling of allocated PGM Smelting capacity.
    - Will this high CAPEX be underpinned if Pd market price collapses?
  - Palladium plays **minor** role in H_2 Economy with limited loadings in LOHC and H_2 Permeable Pd Foils/Films
  - Increasing mined Palladium to PGMs ratio, especially with future Russian mining expansion, will favor Pd.
  - Direct methanol fuel cells beginning commercialization. DMFC's use Palladium

- **Lion Battery Project – Testing using Pd and Pt cathode layers in next generation LiS and LiO_2 LiB R&D**
  - Testing 6-12 grams of Pd per LiB into next generation Lithium Sulfer battery designs continues
  - If successful would resolve any Palladium market surplus very quickly.
  - Lion Project is 51/49% JV with PGM Ltd. & Anglo American
  - Fantastic progress in R&D in next generation Li-Sulphur LiB design work 750 cycles using reasonable amount of Pd/Pt on LiB as Cathode layers.
  - Commercialization in scale still years away.

PLATINUM GROUP METALS

AngloAmerican

- **As we approach a structural surplus in the Palladium market what else can we do?**

Palladium Center - commercially focused R&D, main streams are:

01 Internal development of palladium high-margin products

02 Joint R&D with leading experts

03 Commercialization and business development

Target:
120+ new products by 2030

Our partner network include:

Universities & Industrial parks

Moscow state university

Boreskov Institute of Catalysis

Tomsk polytechnic university

Tongji Uniersity

Shanghai Advanced Research Institute

Wuhan Technological University

End users & manufacturers

NLMK group

Inenergy group

Natura siberica

BriHyNergy

Sino-platinum metals

Nowogen

Hydrogine Technology

Associations & funds

China Precious Metals Industry Committee

Sequoia capital china

X-node

China Hydrogen Alliance

In hydrogen industry we develop new palladium based products across the whole production chain and have ready-to-use ones

Power-to-gas technologies → H2 purification / extracting from gas → Storage and transportation technologies → Gas-to-power technologies

*Examples**

PEM electrolysis | Membrane separation | Liquid organic hydrogen carriers (LOHC) | PEM Fuel Cells

Pd-catalyst for electolyzer

	PdIr prototype	Ir Commercial sample
Activity (I=1,53 B)	**26,8** ↑	10,5
Residual activity	**10,4** ↑	1,5
Δ E (10 mA/sm²)	**300** ↓	370

↑↓ - better than a commercial sample

Membrane for hydrogen purification

	Pd-V(Pd) Prototype	Pd-V Commercial sample
Flow capacity, Ml/(min*cm2)	**15 (T=360°C)** ↑	**3,36 (T=300 °C)**
Hydrogen purity, %	99,99999 ↑	99,5 – 99,99999
Operation temperature, °C	340-400	300-600
Pressure ratio, Bar	5-11	14

↑↓ - better than a commercial sample

Fuel cell Pd-catalyst

	PdPt Prototype	Pt Commercial sample
Activity	**419** ↑	196
Residual activity	**250** ↑	97

↑↓ - better than a commercial sample

Catalyst | Membrane

Fundamental R&D: research in B2C, fast growing B2B and regulated markets to open new 50t+ mega applications for palladium

B2C mega-markets

Examples

- **Food packaging:**
recombination of hydrogen for oxygen residues removal
- **Electronics and household devices**
electro-luminescence
- **Household chemicals:**
Color characteristics

Markets under regulation (current or potential)

- **Carbon and methane capture**
catalytic activity of CO_2/methane conversion to organic product
- **Petroleum and plastic products utilization**
catalytic activities to destruction reaction
- **Water disinfection**
catalytic activity to conversion of chloride ions into a decontaminating agent

Fast growing B2B markets

- **Batteries technology:**
preventing the dendrites formation
- **Superconductors:**
electrical conductivity at room temperature
- **Computing infrastructure**
magnetic susceptibility for memory devices

Lion Battery Project

The use of PGMs on Next Gen Li-Sulphur Batteries

Lion BATTERY TECHNOLOGIES

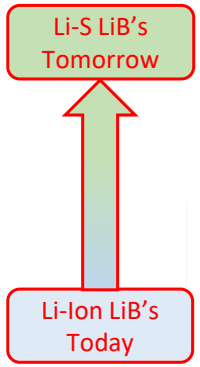
Next Generation PGM Batteries

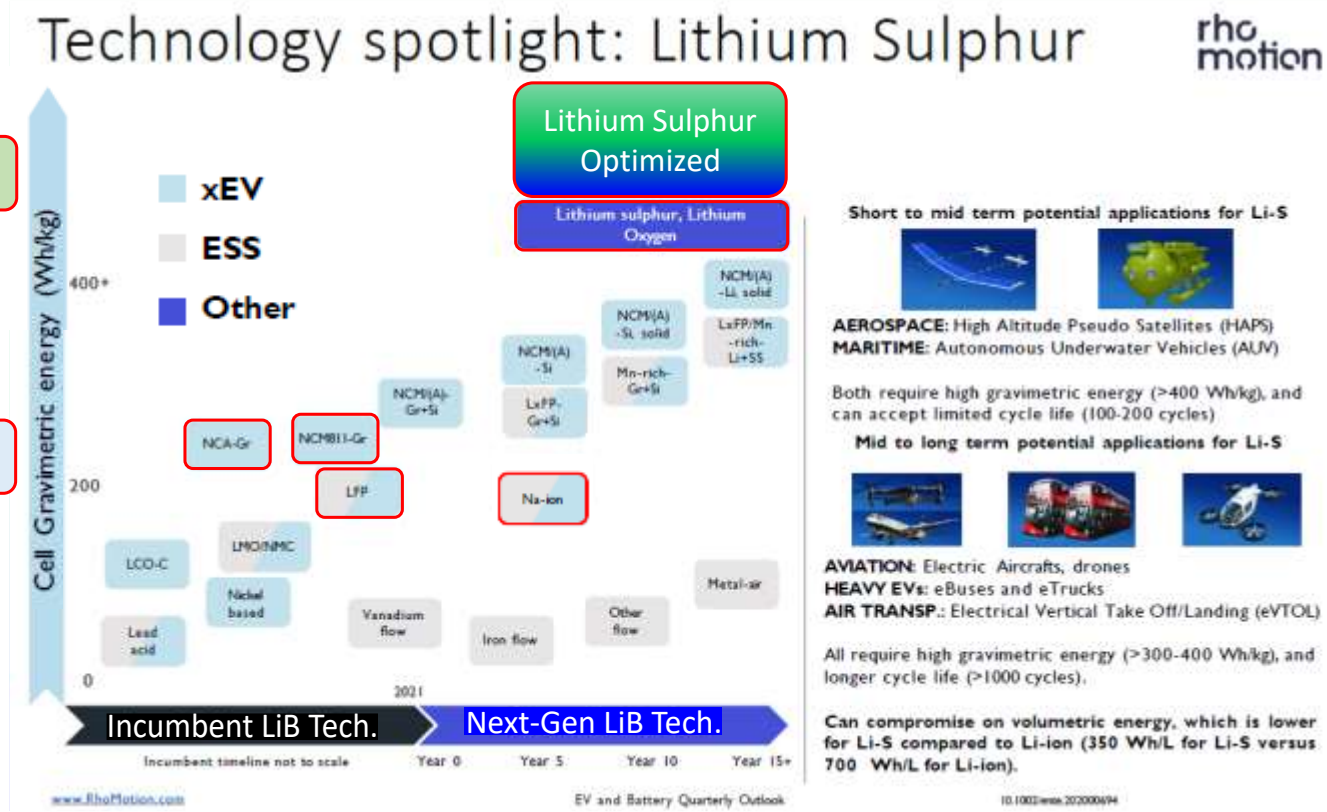
October 2023

PLATINUM GROUP METALS

FIU

AngloAmerican





Lion Battery research efforts are focused on developing beyond lithium-ion chemistries and enhancing existing lithium metal anode batteries.

- ❑ Switch from intercalation chemistry to reaction chemistry opens the door for a group of materials new to the battery field - PGMs as catalysts to charge and discharge reactions.
- ❑ PGMs can allow faster (higher C-rate), more reproducible (more cycles), and higher efficiency of operation in the batteries (higher Coulombic efficiency).
- ❑ PGMs can be used in custom designed electrolytes for use in many types of batteries
- ❑ Five patents have been granted with additional patents pending based on work to date. More patents recently added.

The Hydrogen Economy

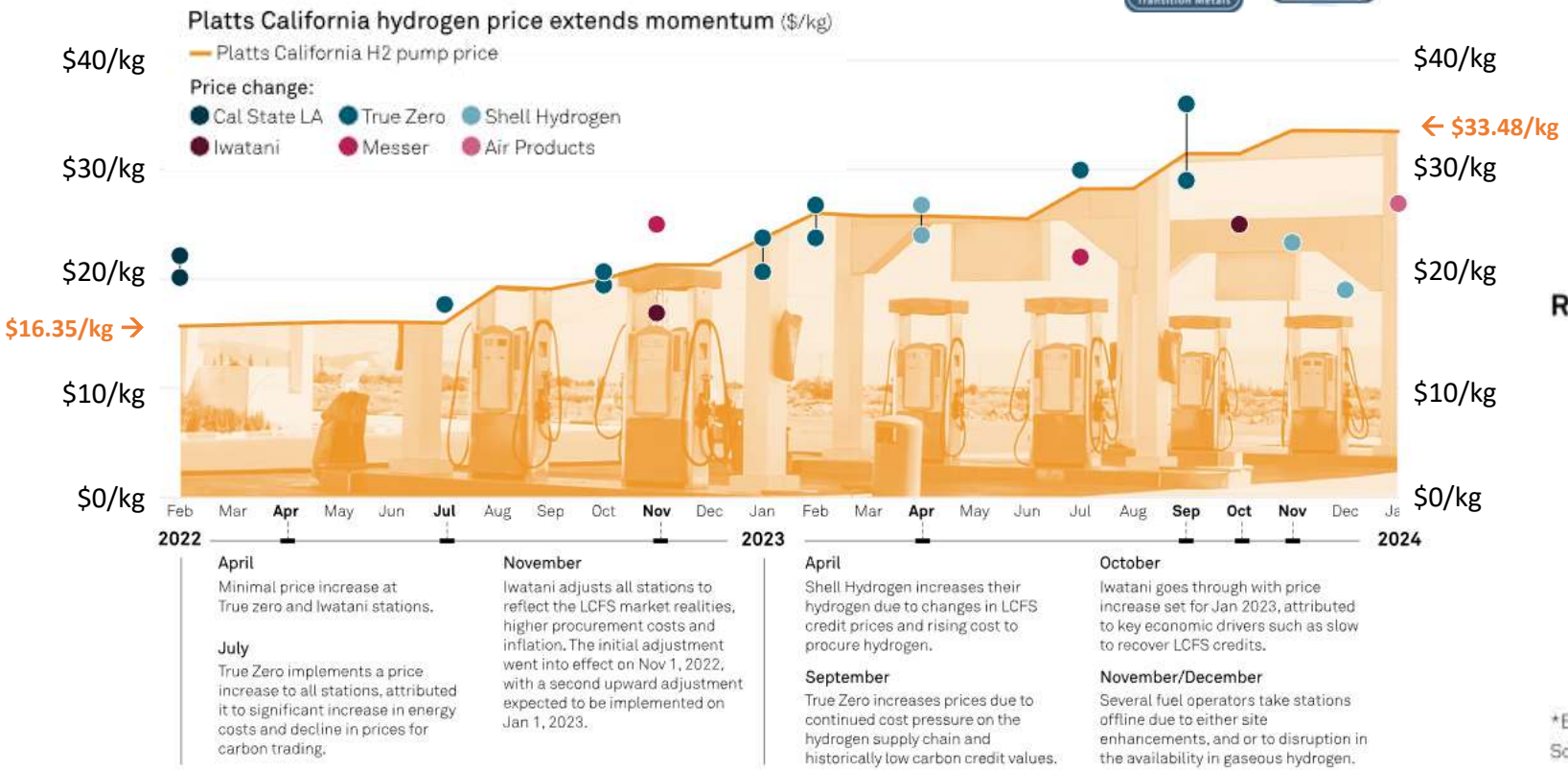
Is an uphill push

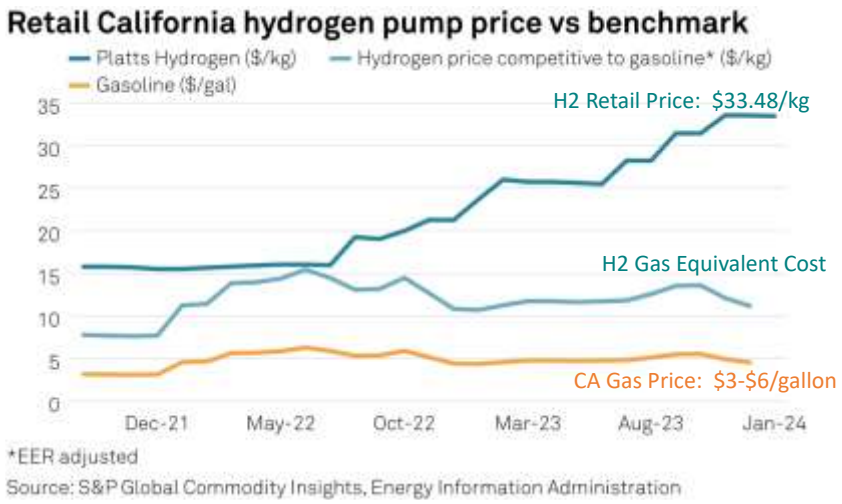
H_2 Economy Critical Minerals

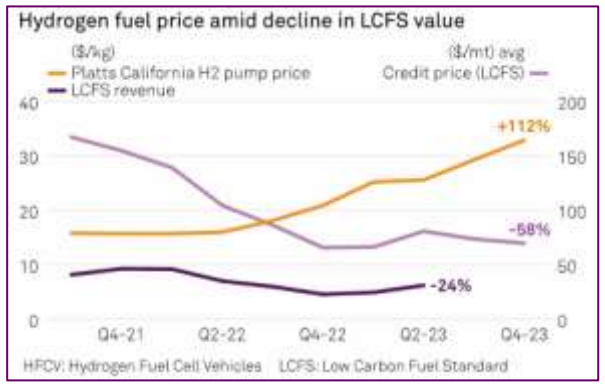
- Platinum
- Iridium
- Ruthenium
- Palladium
- Copper
- Nickel

Hydrogen Economy Explosive Costs & Deteriorating PGM (Pt Ir Ru) Supply Outlook are the Concerns

Hydrogen Economy





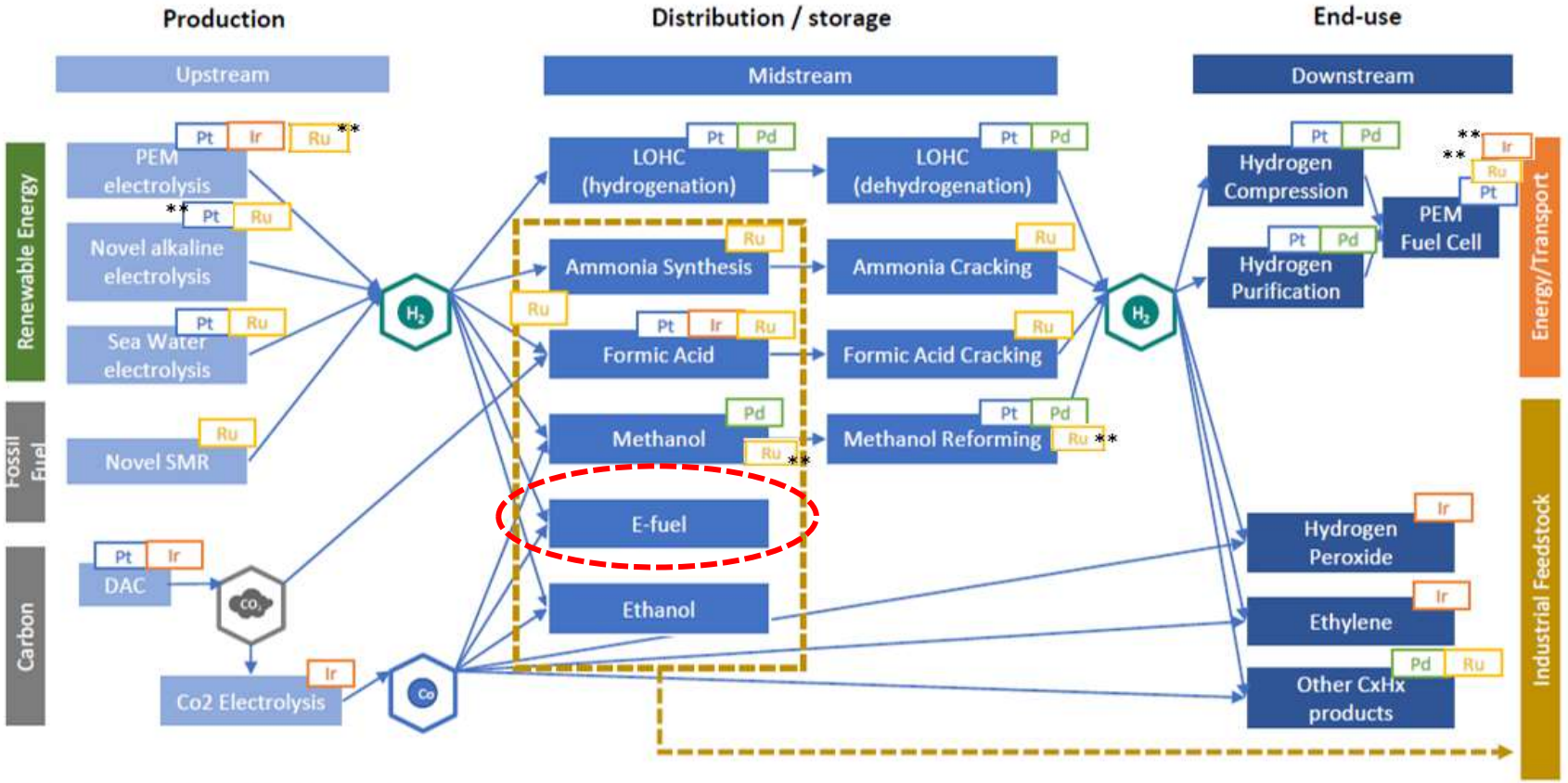


What are LCFS (Low Carbon Fuel Standard) Credits?

- **Carbon Tax Credits**
- In the LCFS market, low CI fuel producers can register to produce LCFS credits for the amount of fuel dispensed. High CI fuel producers or distributors then purchase those credits to offset the amount of high CI fuel dispensed in their portfolio. The price paid for LCFS credits varies with supply and demand, the amount of low CI fuels generating credits vs. the amount of high CI fuels consuming those credits.

PGMs and Hydrogen are Synonymous:

Making, storing / distributing and using hydrogen requires PGMs



Source: AP Ventures / Mitsubishi Corporation **A few corrections by Matt

One segment taking off.

H_2 Economy

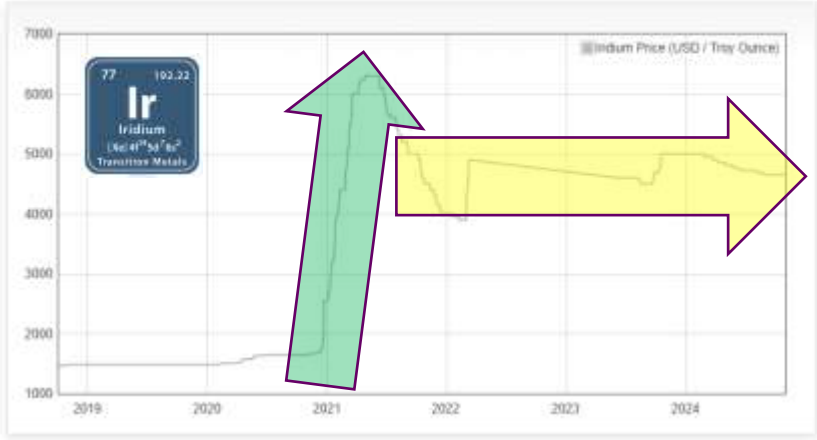
- **Platinum** demand highest in transportation PEM fuel cells.
- **Iridium** demand highest in green H_2 PEM electrolyzers.
- **Ruthenium** used more broadly in transportation PEM fuel cells 94:6 Pt:Ru ratio.
  - **Ammonia** synthesis and ammonia cracking both require Ruthenium.
- **Palladium and Rhodium** use in H_2 economy is minimal weight.
  - Pd used in Direct Methanol Fuel Cells
  - Pd used in methanol production and methanol cracking.
  - Pd used in H_2 purification

H_2 Economy PGM's - Market Price Trend & Outlook

Platinum Prices for the Last 5 Years

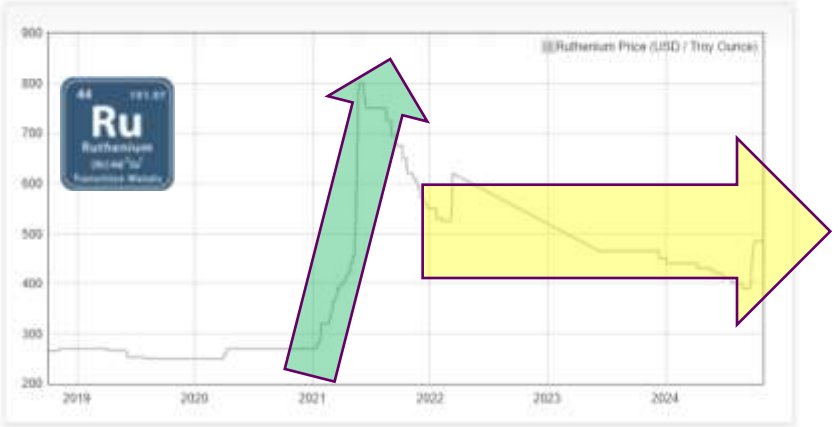
Platinum - Friday pm ↑ $907/toz

Iridium Prices for the Last 5 Years



Iridium EIB Friday ↑ $4,950/toz

Ruthenium Prices for the Last 5 Years



BASF EIB US Friday Ask: Ruthenium → $465/toz

Outlook

↑ Hydrogen Economy Demand ensures higher pricing long-term.

- FCEV Pt loadings far (30x) greater than AutoCatalyst today.
- Variable Renewables will make H_2 energy storage essential, ensuring Pt demand.
- Diverse Pt demand – Chemical, Electrical, ElectroChem, Petrol, Glass Production, Medical, etc.

↑ Growing and diverse Ir demand, limited design alternatives, plus new H_2 PEM electrolyzer demand for Green Hydrogen.

- Short-term: Watch 2023 S. Afrian PGM mining supply disruptions from record Eskom power-grid load shedding.
- Long-term: Urgent need for PEM Electrolyzer Ir design thrifting in progress.

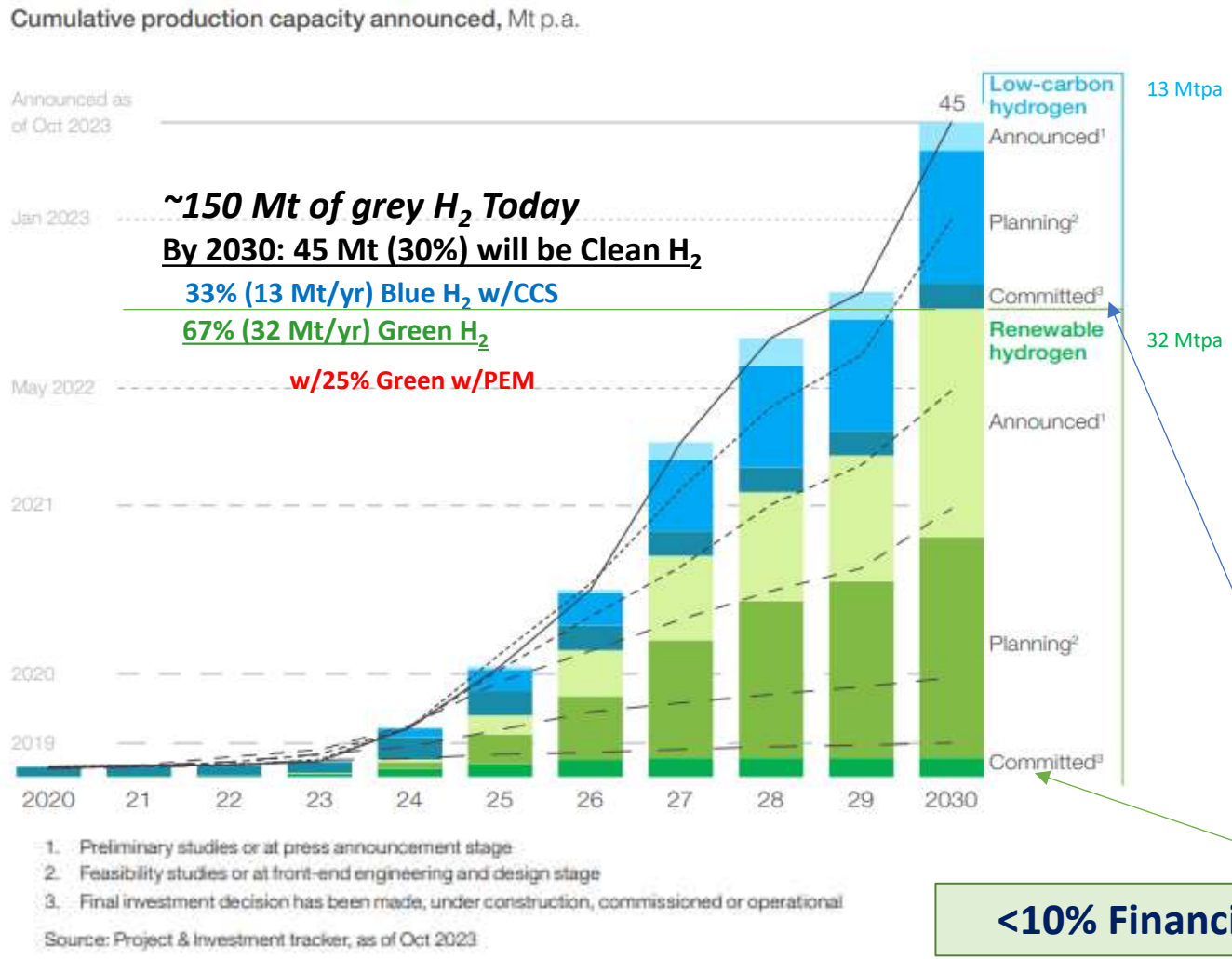
↑ Growing diverse Ru demand. Exception is 40% HDD market decline. Pt/Ru HDD FCEV's now commonplace. Ru as alternative to Ir in H_2 electrolyzers.

- Short-term: HDD and electronics market weakness in PVD targets.
- Long-term: Growing use in transportation PEM fuel cells and smart glass. Also growing use of Ir/Ru alloys for Green H_2 electrolyzers. Potential use in future plastics recycling.

Accelerating Clean Hydrogen Plan

Dec'23 2030 plan is now for 238GW (Final 2050 target 600-900 GW)

December 2023 Projections



H_2 Council 2050 Goal:
660 – 900 Mtpa of Clean H_2

Base Case: 1,031 GW @ 660Mt H_2 w/25% PEM
to
High Case: 1,687 GW @ 900Mt H2 w/30% PEM

- Financially committed projects still < 10% of plan
- Low-carbon Blue H_2 90% projects in N. America.
- ~75% installed electrolyzers alkaline
- ~25% PEM electrolyzer capacity installed (mostly EU)

1,011 projects with full or partial commissioning (COD) by 2030 **+407** projects without specified COD or COD post-2030 (not shown)

Hydrogen Insights 2023 – Dec'23

<10% Financing complete & committed

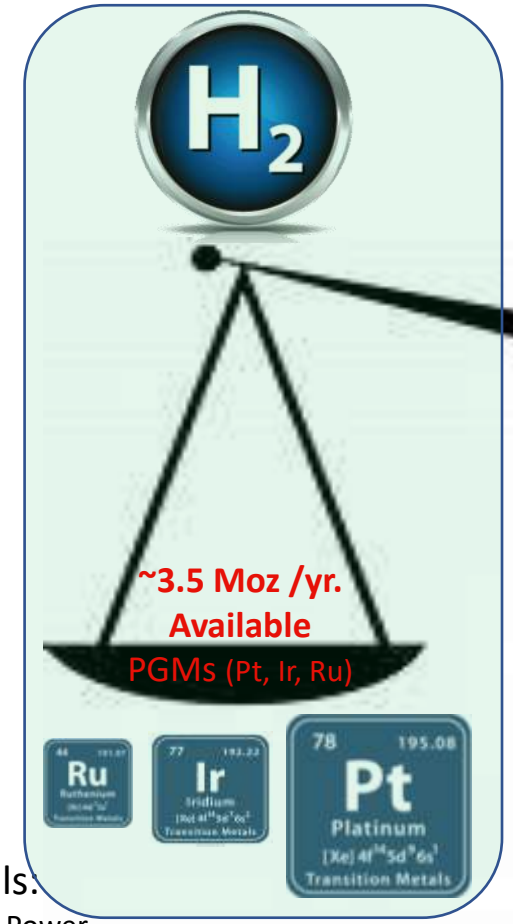
The H_2 Economy is Going to be Huge for PGM's … Or Is It?

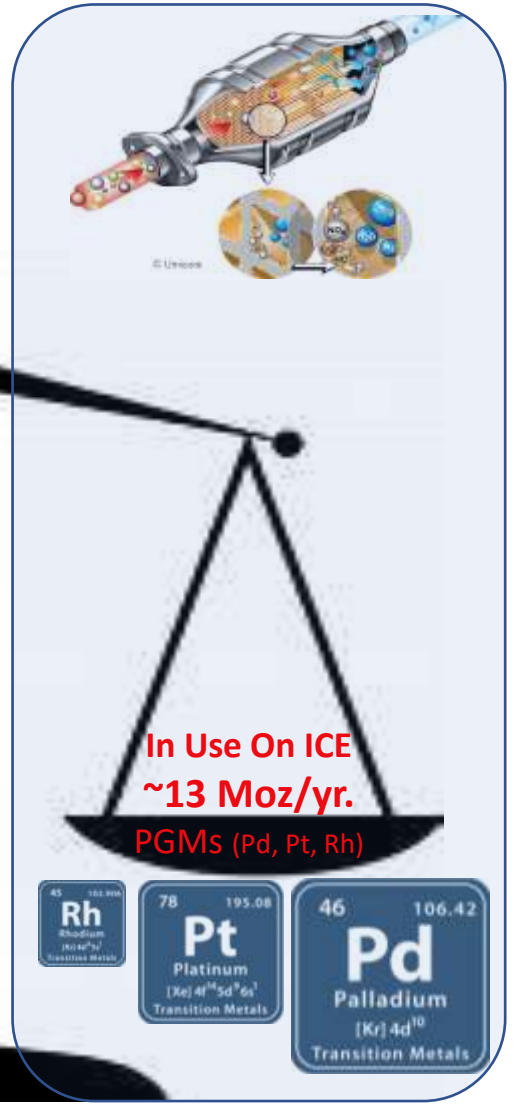
Transportation
PEM Fuel Cells
LDV and HDV Vehicles, Trucks, Trains, Planes, Marine, Lifts

H_2 Transport / Storage / Management

LOHC Conversions

Green H_2 Elelctrolyzers:
PEM & Direct Methanol





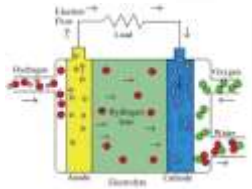
Auto Catalyst
LDV gas and diesel
LDV Hybrids
LDV PHEVs
HDV diesel

NO_X Sensors
O_2 Sensors
Temperature Sensors

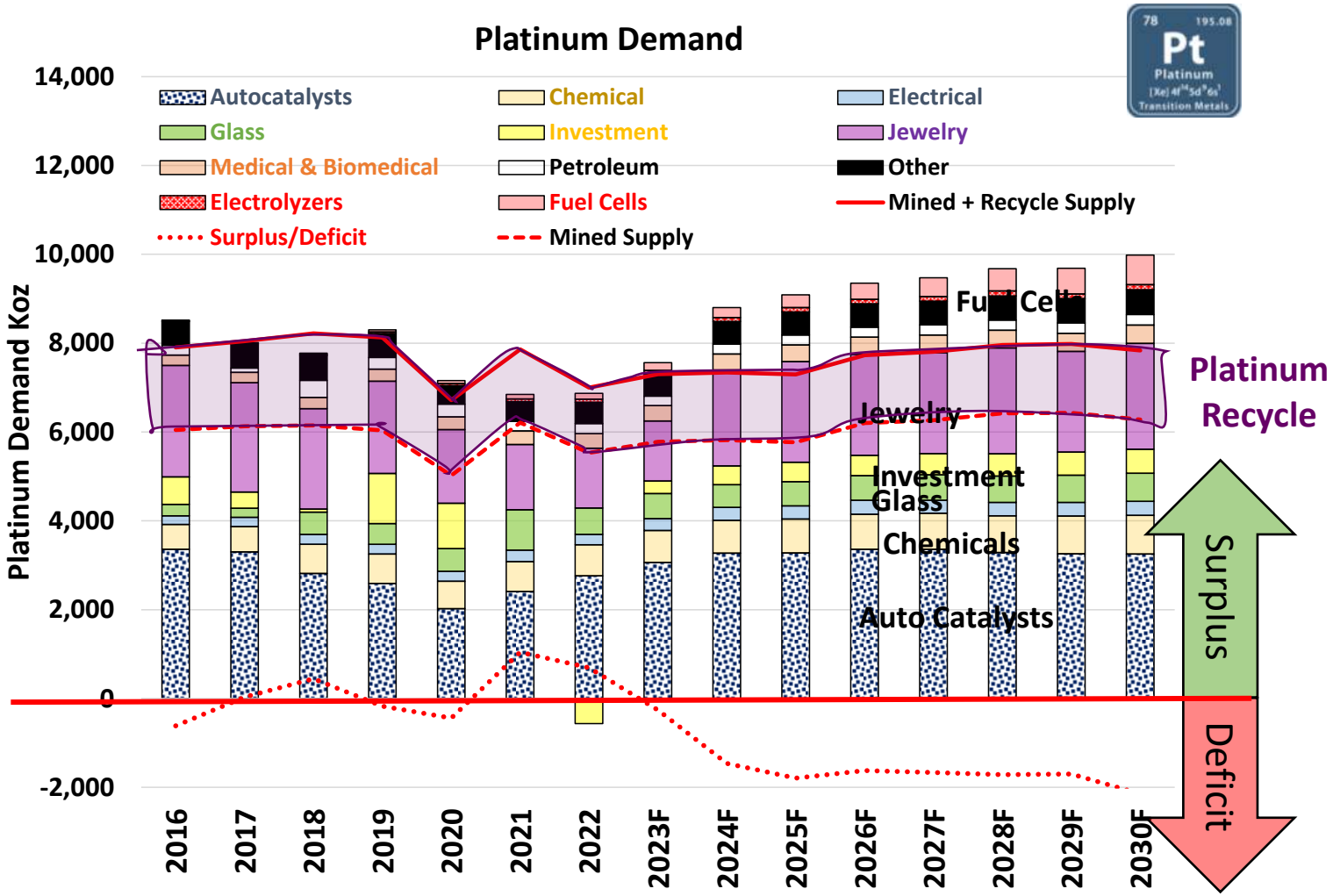
Auto Spark Plugs
Pt, Pt/Ir, Ir, Ru

Reversible PEM Fuel Cells:
Power-To-Gas & Gas-To-Power

Power to X
GREEN FUTURE

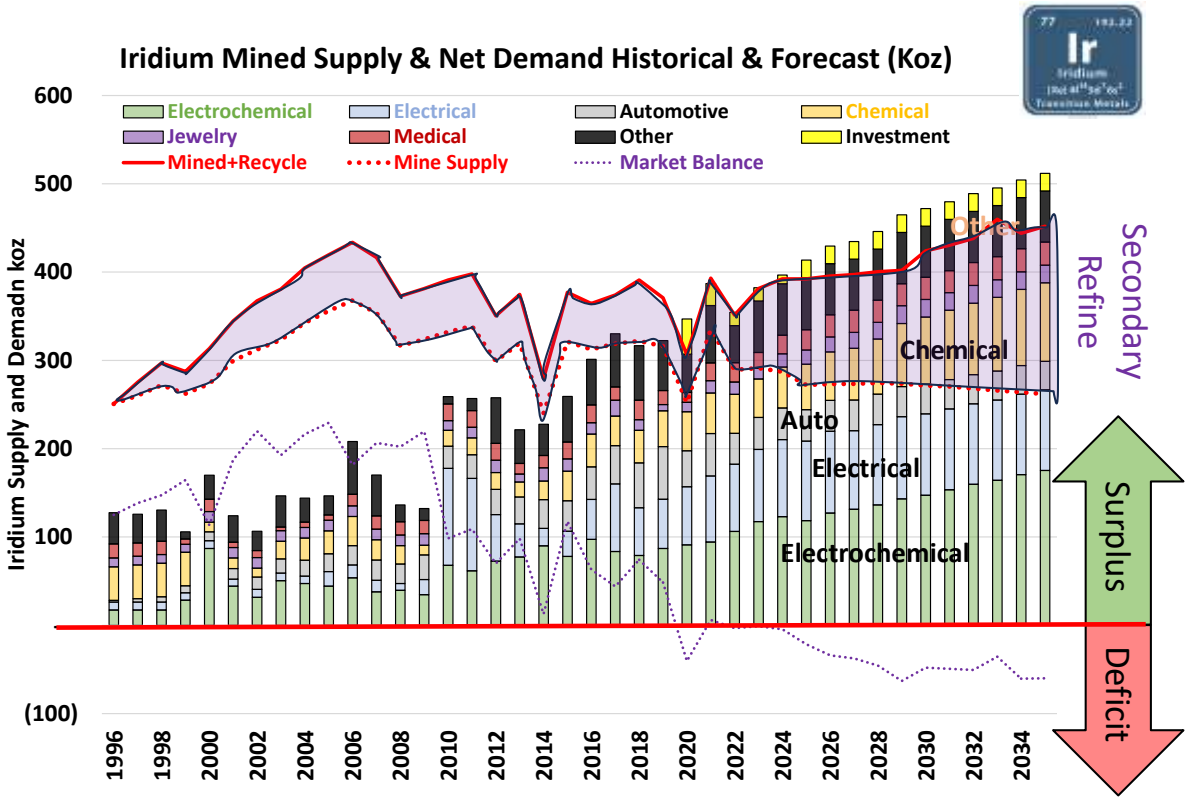


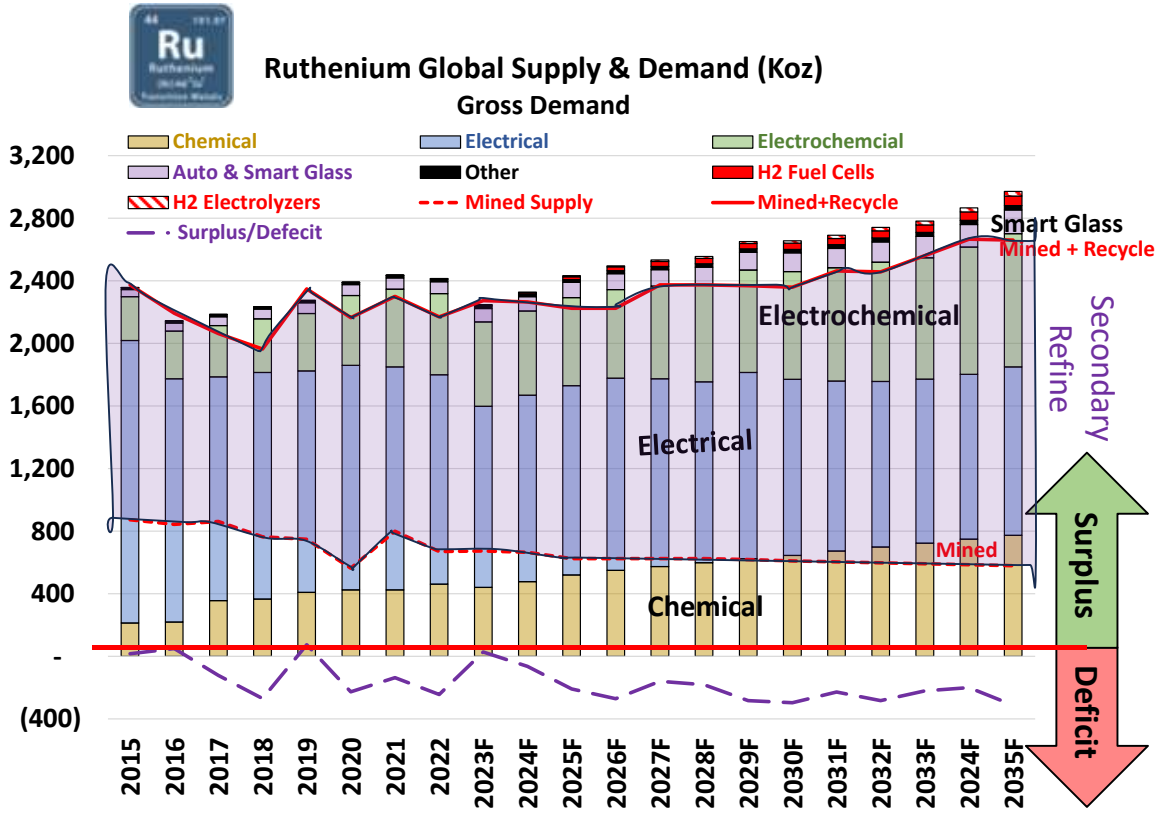
Platinum Market Summary



New Gross Demand Models

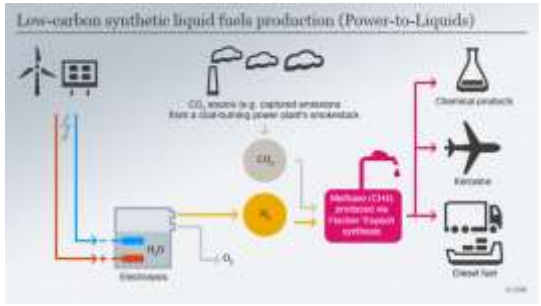
Iridium Market Summary

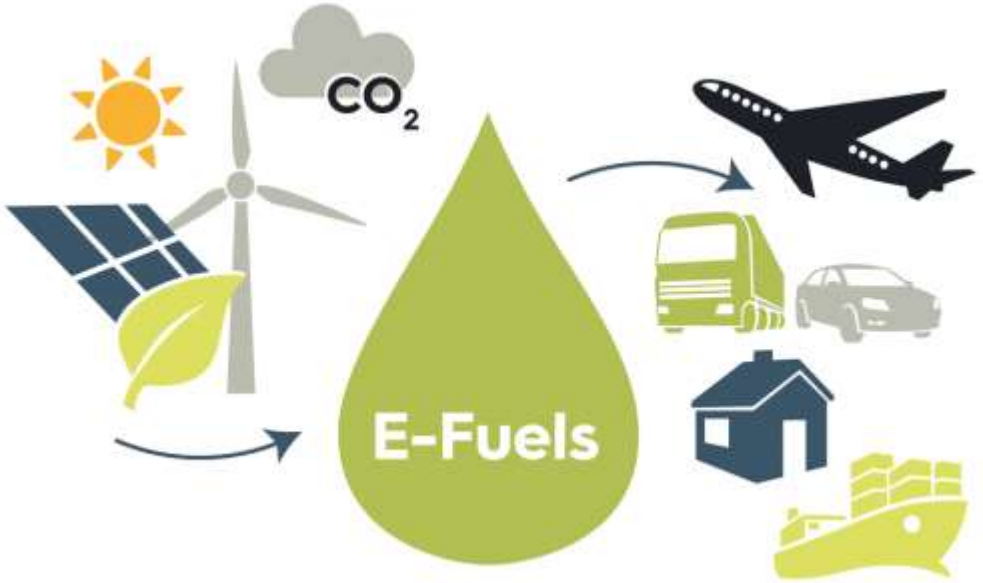


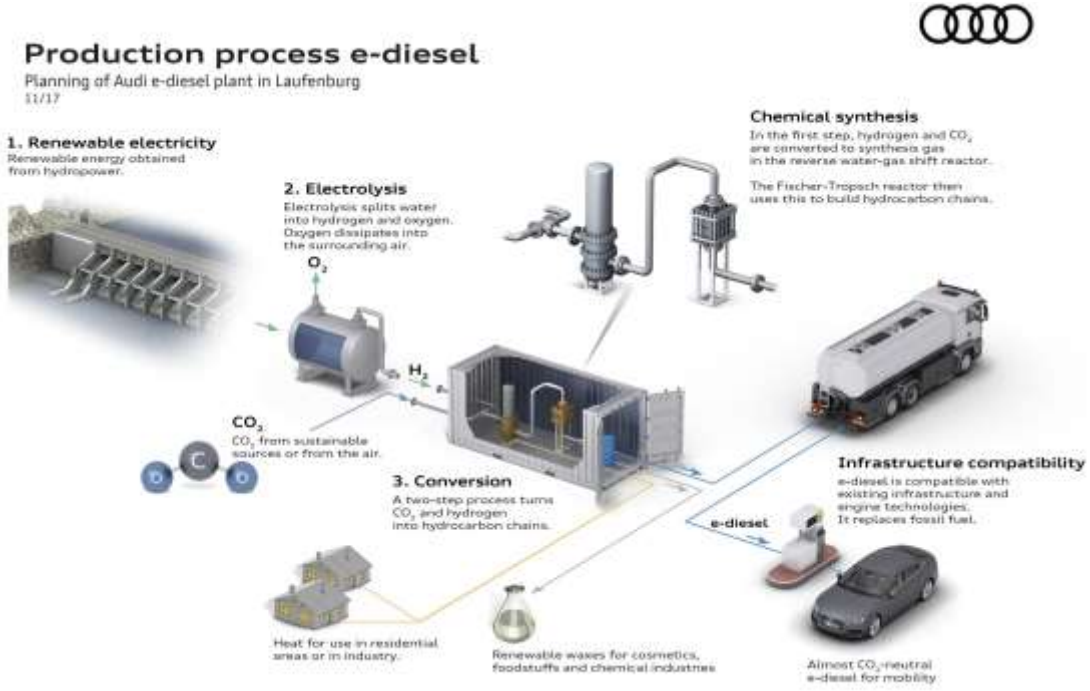


eFuels Leveraging PGMs - A sleeper category

- eFuel production is based on the extraction of hydrogen. This happens by means of an electrolysis process that breaks down into its components of H_2 and oxygen.
- In a second process step, with the aid of e.g. Fischer-Tropsch synthesis, the H_2 is combined with CO_2 and converted into a liquid energy carrier: eFuel. Under high pressure using a catalyst, the hydrogen binds with the CO_2. Because electricity is used for the production of eFuels, the procedure is known as a power-to-liquid process: electricity is converted into a synthetic liquid that is easy to store and simple to transport.
- SAF costs are 120%–700% higher than fossil-based jet fuel costs. SAF reduces CO^2 emissions between 27% - 87%. The lack of producer incentives poses a significant hurdle to SAF adoption.







Sustainable Aviation Flights In The News

2021

First commercial airline flight using 100% drop-in SAF enabled by technology from Virent and Johnson Matthey

VIRENT

09 December 2021

2023

Flight100: Virgin Atlantic flies its first 100% Sustainable Aviation Fuel flight

28 November 2023

2023

Emirates first airline to operate demonstration flight with 100% Sustainable Aviation Fuel

2024

Airbus leads investor group bankrolling a new $200 million sustainable aviation fuel fund

BY STEVE KERCH

JULY 23, 2024 • 2 MIN READ

2024

USA TODAY + Follow 1.1M Followers

United Airlines will begin using sustainable aviation fuel in Chicago this summer

Story by Zach Wichter, USA TODAY • 3h • 2 min read

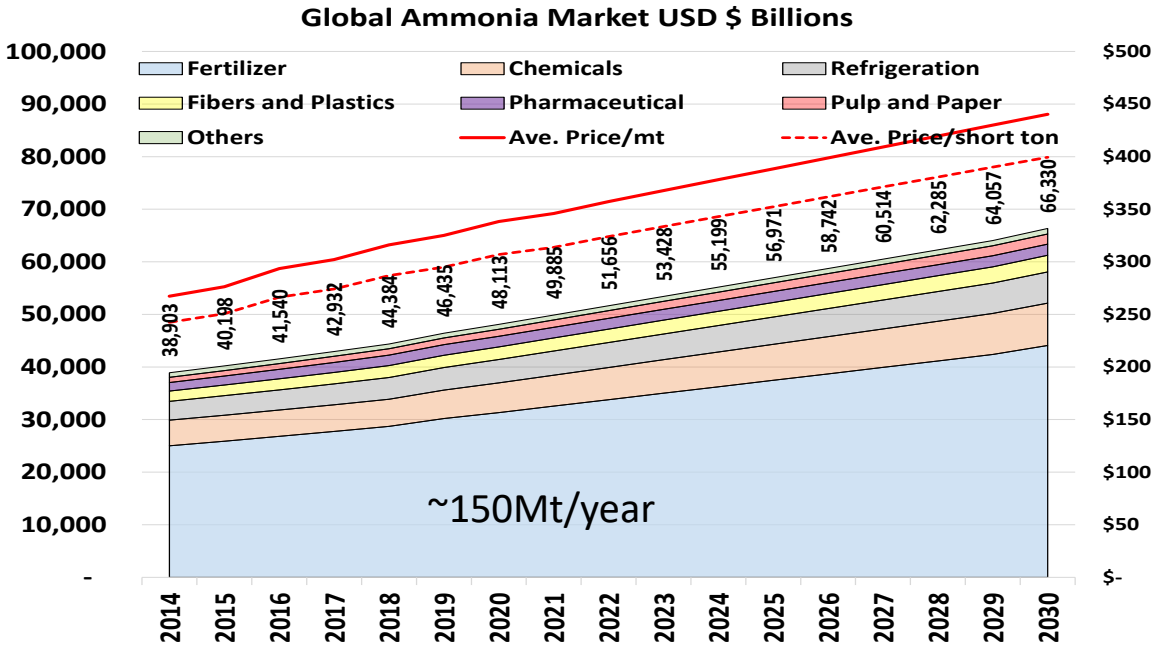
Ammonia Market

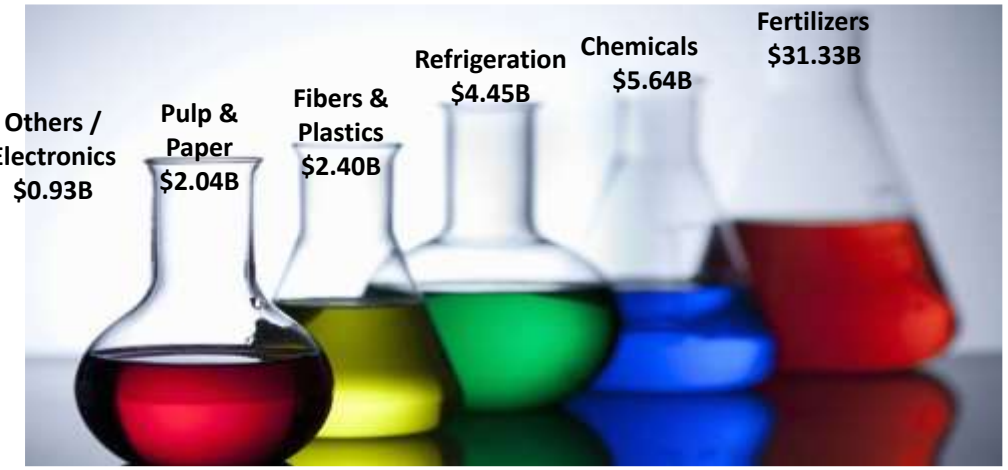
Ammonia growth as LOHC and Marine Fuel

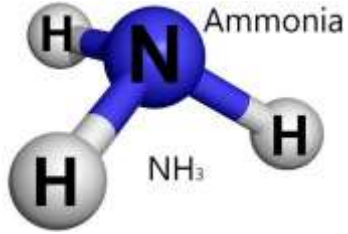
Ammonia Critical Minerals

- Ruthenium
- Iridium & Platinum H2 Catalyst
- Nickel
- Molybdenum

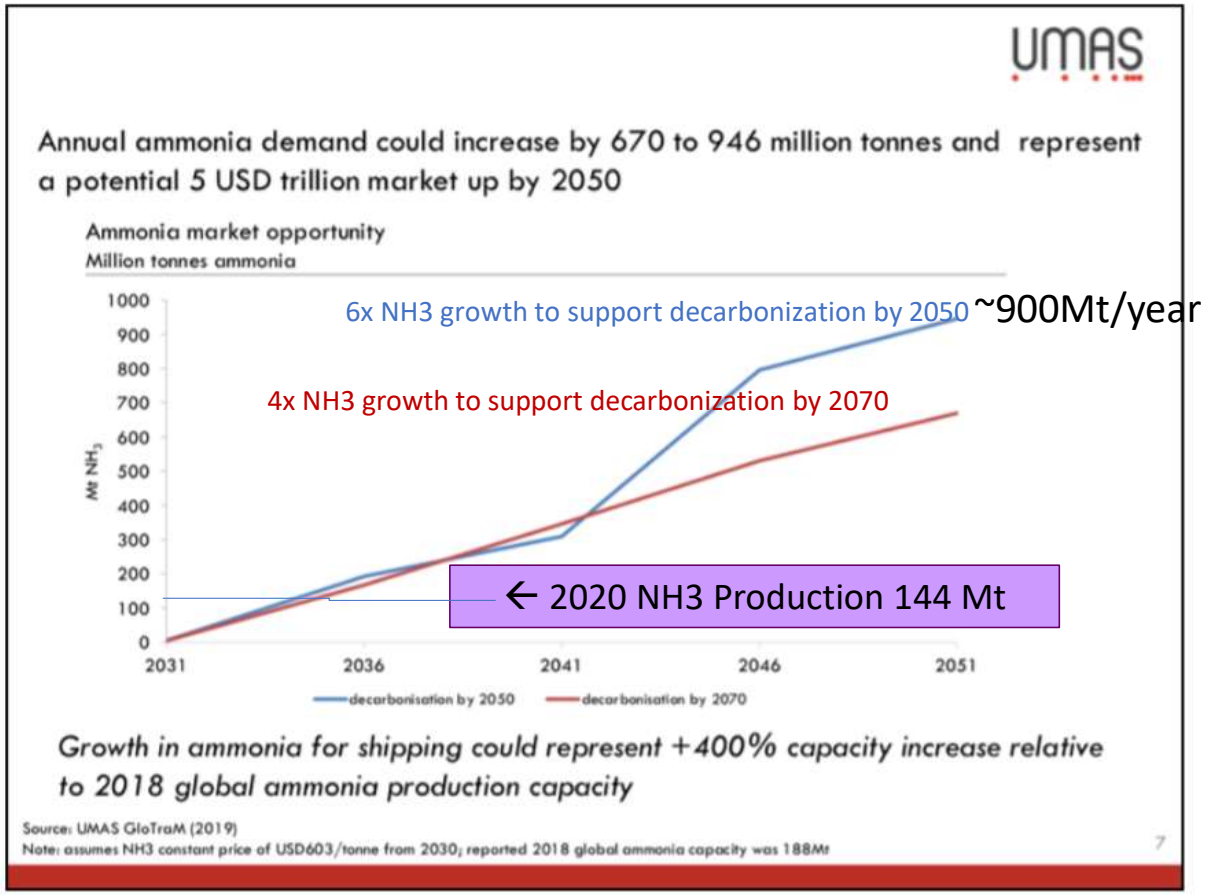
Ammonia Market Today





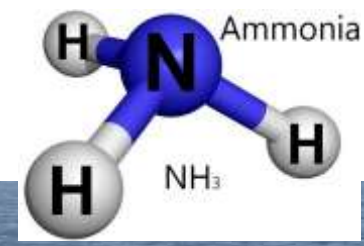


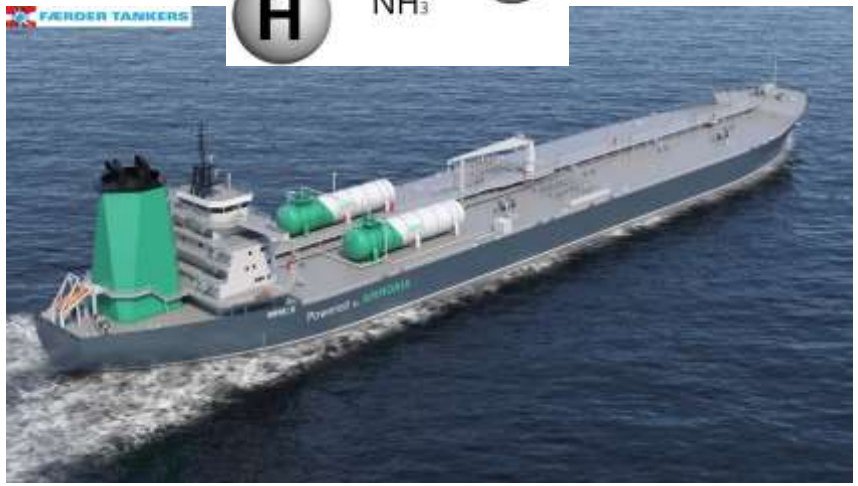
What If Ammonia market 4x to 6x for use as a feedstock in shipping and heavy industry



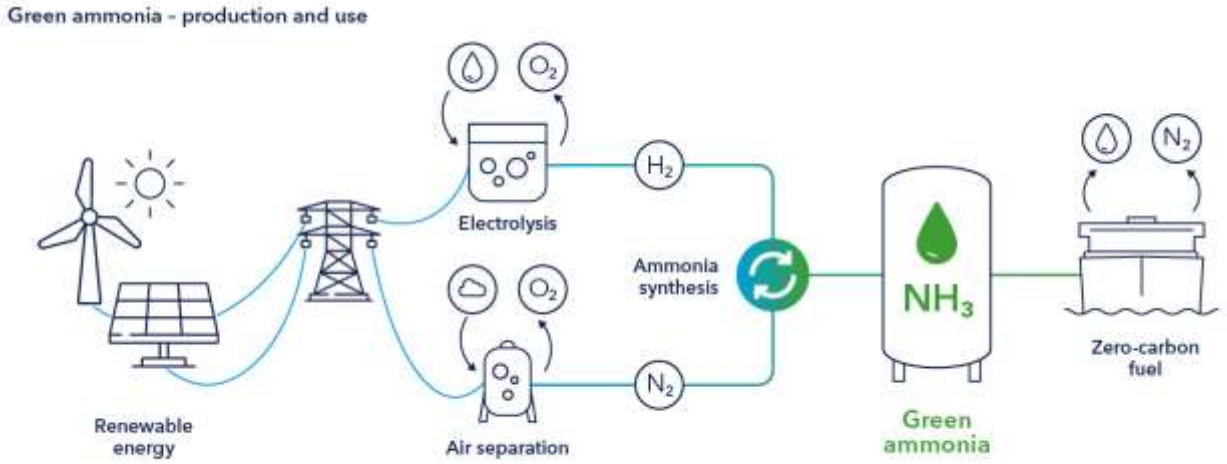
https://www.globalmaritimeforum.org/news/the-scale-of-investment-needed-to-decarbonize-international-shipping

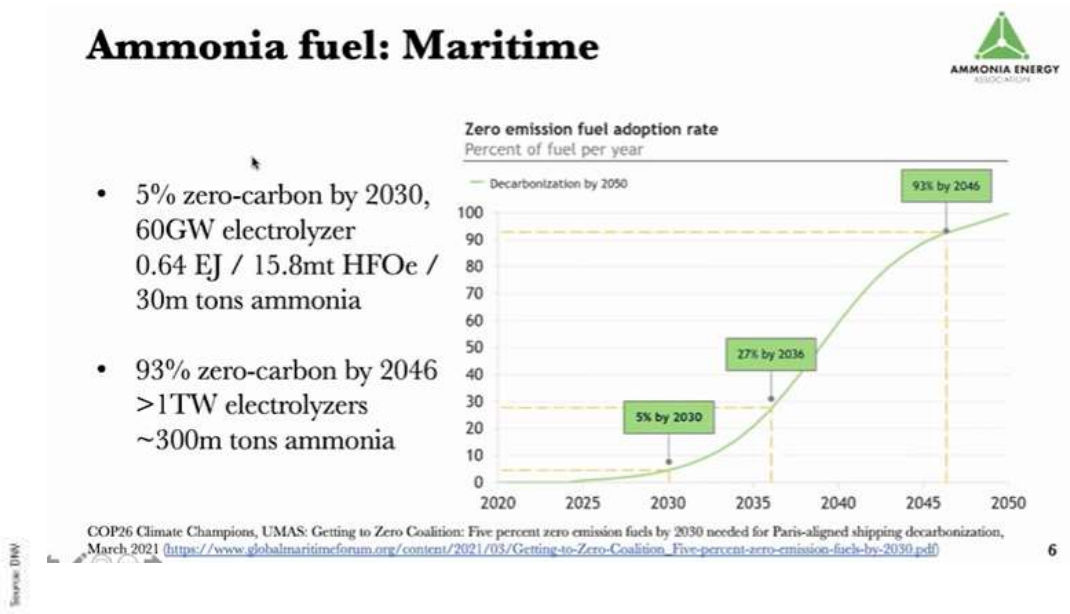
Ammonia as a feedstock in shipping and heavy industry





- Green Hydrogen based synthetic Green Ammonia
- Requires up to 1 TerraWatt of electrolyzers by 2050 to support 300Mt of Green Ammonia
- Could impact 93+% of maritime emissions
- Opportunity for Ru in synthetic ammonia production as well as well as in cracking ammonia.
- Amogy focused on ammonia – along with Mitsubishi

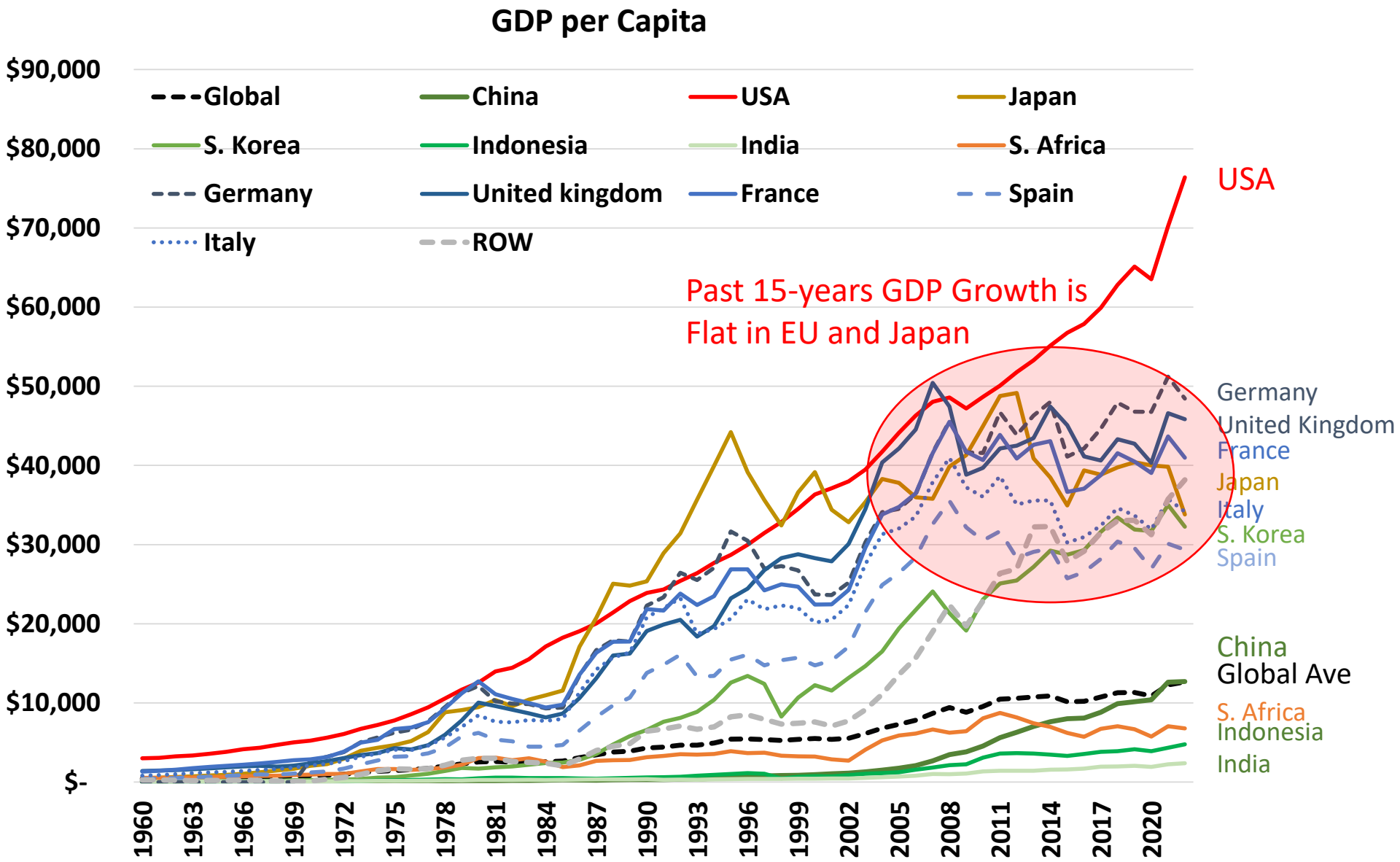




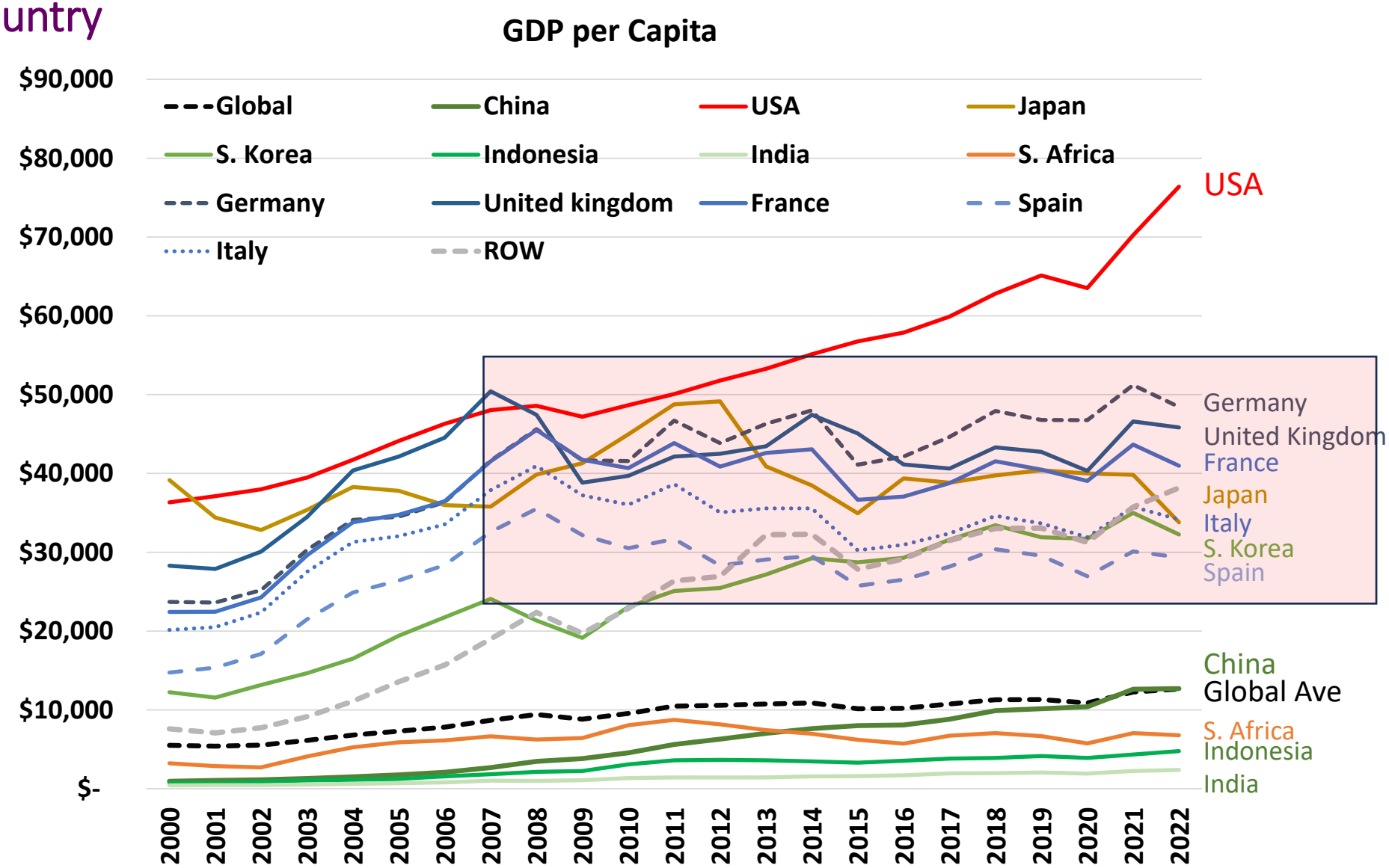
The Economics of Clean Energy

It all costs more and drives commodity Inflation

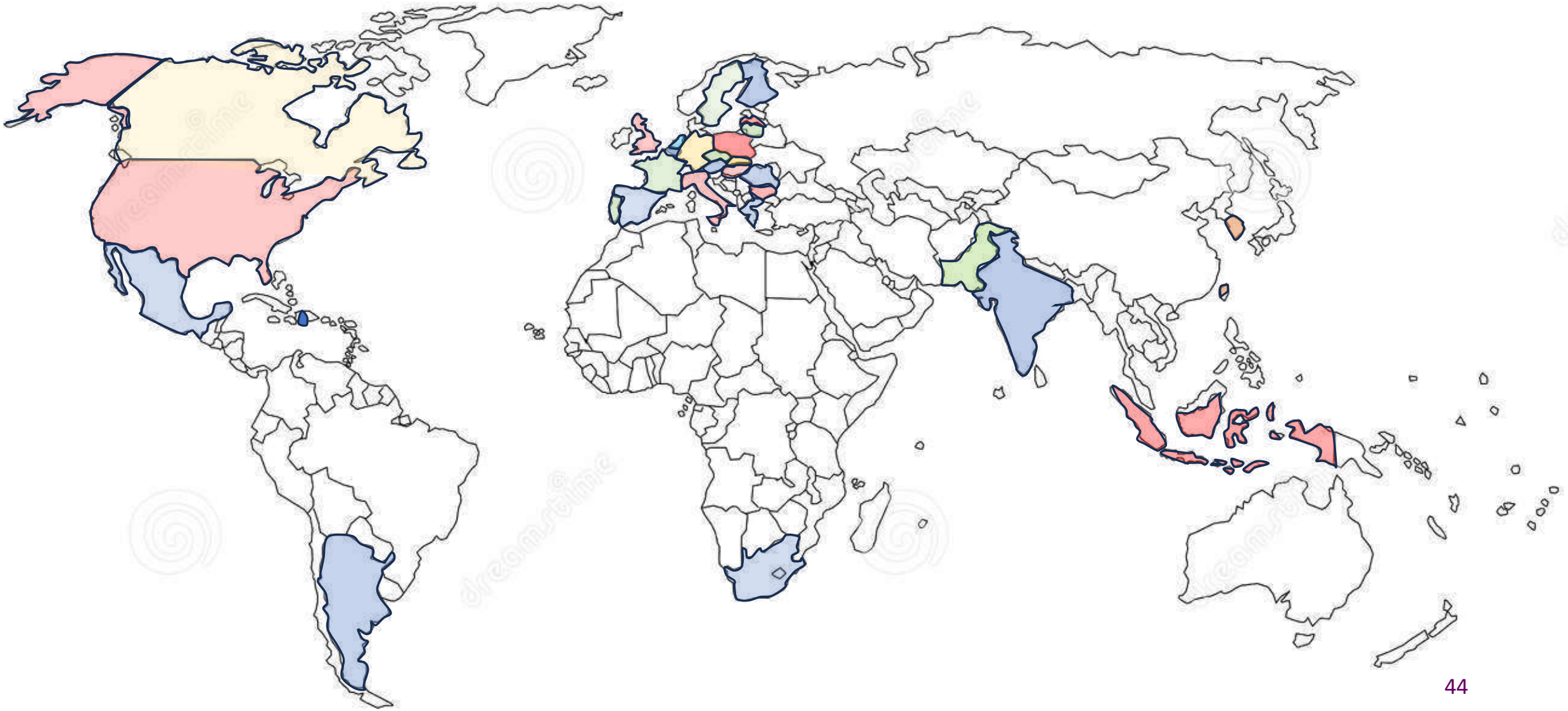
GDP By Country



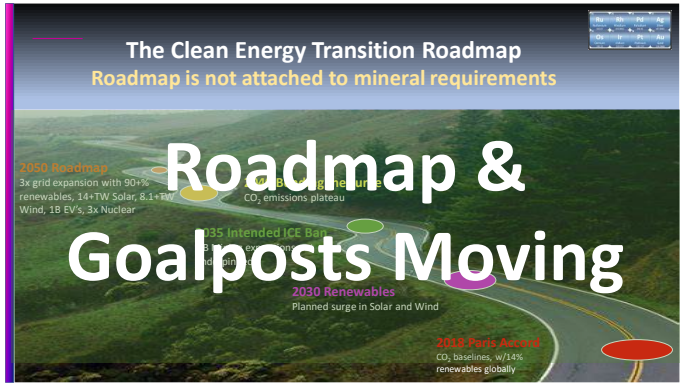
GDP By Country

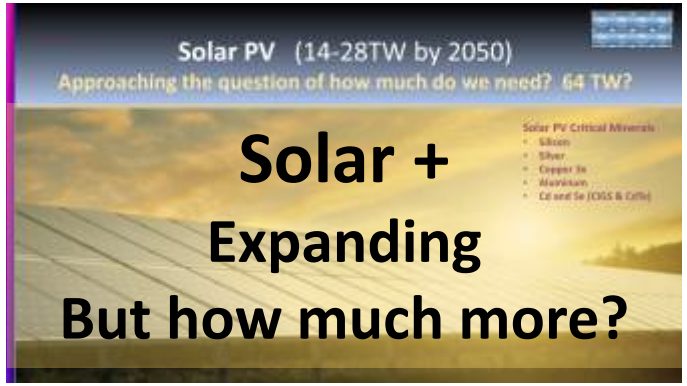


The Political Pendulum Swinging More Conservative Globally in 2024?



Economics Summary





Economics Summary - Page 2

Green Rush - Mining The Energy Revolution

is your guide to understanding energy transition

2024 Weekly Kitco Produced News Program

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2 

Gold between $2,700 to $3,000 - WGC's J
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'An ominous task' — filling the demand for clean hydrogen & required PGM
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Why palladium, rhodium 'are really going to be challenged' - Matt Watson on less
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The Future Of PGM's: Forecast for "PGM Basket Strain"

- **Increased Long-Term Palladium & Rhodium Accumulated Surplus**
  - Both Pd/Rh have centralized 85+% demand from Auto Catalysts alone. Current macro-economic slowdown has dramatically lowered global vehicle sales.
  - PGM Basket price is dropping as Pd and Rh drop from their current macro-economic driven ICE build shortfall.
  - Palladium and Rhodium auto catalyst recycle returns will continue for decades.
  - Need to restart a "Palladium Challenge" to promote Pd use and the development of new applications.

- **Increased Long-Term Platinum Demand for Fuel Cells & Green H_2 Electrolyzers**
  - 70-80% of the forecast Pt demand is in the transportation Gas-To-Power transportation PEMs.
  - Remaining demand from H_2 conversions and green electrolyzers.
  - Current devitrified Pt demand mix fairy sticky, few design swap alternatives

- **Increased Long-Term Iridium Demand for Fuel Cells & Green H_2 Electrolyzers**
  - Primary Iridium forecast demand is from Green H_2 PEM Electrolyzer (today around 25%-50% of the electrolyzer mix)
  - 30x+ Ir PEM loadings design thrifting from a 2020 baseline needed. Key available design swaps include Pt and Ru.
  - Growing used of Mixed Metal Oxides (Electrowinning base metals, chlor-alkali, electrochemistry applications, PCB electro-plating, water treatment, BWTS, etc.)

- **Long-Term Ruthenium Demand for Ammonia Fab/Cracking, Fuel Cells & Green H_2 Electrolyzers**
  - Current Ru demand mix is fairly sticky. Thick Film Ru Resistors and HDD Ru PVD target demand will both decline in time.
  - Potential growth in recycling mixed plastics and smart glass.
  - Nearly 2x demand vs mine supply supported with significant secondary refine capacity.

- **PGM Mining Pt/Ir/Ru (shortages) vs Pd/Rh (surpluses) – Basket Imbalance Growing**
  - PGM mining is shifting into Palladium rich deposits in S. Africa's Northern Limb, Zimbabwe, Russia, & N. America.
  - The richest Pt, Ir, and Ru deposits are South Africa's Bushveld Complex's Western & Eastern Limb.
  - Limited greenfield and brownfield PGM projects aligned with the Western and Eastern Limb.
  - South Africa power supply growing instability, social discord and theft adding to shaky outlook.
  - Mining Investment is and will remain diluted with competing Critical Minerals demands, especially Li, Ni, Co and Graphite for LiB's

- **PGM Recycle Pt/Ir/Ru Recycle Growth Occuring**
  - Platinum has some 46mt recycle, and only 200mt mined/year. Low Pt ICE Auto Catalyst recycle yields due to SiC/TiAlO remain.
  - Iridium has some 8-9mt recycle, and only 8 mt mined/year. Working on increasing Ir recycle.
  - Ruthenium has some 65mt recycle, and only 23mt mined/year. Huge recirculating populations of Ruthenium demand.

Near term macro-economic weakness Pt, Ir and Ru all still vulnerable to some downside

Precious Metals Commodity Management LLC

PM Market Research, Hedging Strategies,

Thrifting Strategies, Trading Support, Risk Management

Utilizing extensive experience in the Precious Metals Commodity markets to help clients make better decision, reduce costs, drive thrifting activities, improve trading performance, reduce risks, create and implement hedging strategies.

Matt Watson
Founder/President

Potential Deep Dive Topics with Your Organization

- **Electric Vehicles**
  - Li, Ni, Co, Graphite and NdFeB (REE)
  - NiP or FerroNickel and Cobalt ESG Issues including emissions: 90t CO_2/t processed
  - Global power grid impact: Need to grow grid 50% by 2050 just to charge the 2B EV's on the road in 2050. Overall plan is to triple to global power grid by 2050.
  - The Hybrid/PHEV Versus Full Range BEV mineral requirements (the Toyota argument)
  - Developing direct extraction on the lowest Li grade Lithium Brines are key to breaking the Lithium supply wide open.

- **Internal Combustion Engines – Emission Control Systems**
  - ICE remain longer than most realize. Hybrids + ICE both with increased PGMs
  - Remaining emission standards evolution & loadings outlooks by region.
  - Latest and next generation NO_X standards forcing big reduction, pressure on Rh to remain.
  - Pd, Rh, Pt auto catalyst demand forecast, higher than most think.
  - NdFeB – REE's needed, especially Nd for Magnets for EV Motors
  - Auto Catalyst recycle at 20 years scrap age. Forecast Smelting Capacity Needs

- **Recycle Market Outlook**
  - Auto Catalyst smelting capacity needs to double to meet growing demands. Increasing Pd recycle returns plus mining will drive structural surplus, and price to roll over after 2030
  - AutoCat, AutoCat Recycle, and E-Waste Market Risk: Umicore potential acquisition by LG Chem could create huge opportunities.
  - Fuel Cell and Electrolyzer recycle outlook
  - Li-Battery Recycle – LFP are economically under water for treatment charges. Early recycle nameplate capacity far exceeds demand. Big recyclers partnering with LiB OEMs for process scrap to fill 30% of the early mix.
  - E-Waste Market & Copper Recycle
  - Solar PV Recycle – It's all about the economics. Al framing, Glass, Ag, Cu, and Si
  - Electronics & low grade silver recycle

- **Electrification Metals Cu Ag and Al**
  - Need to double all of the copper mined in the past 1,500 years to meet the copper demand of the next 30-years.
  - Declining Ag and Cu ore head grades
  - Existing USGS Known Reserves are not enough
  - Acceleration of demand from Clean Energy Transition
  - LFP LiB's use 30-50% more Copper than NCA/NCM designs

- **Nuclear**
  - Growing heavy industry, and pink H_2 demand.
  - Responsive technology pairs with variable renewables better
  - Silver in the RCCA's
  - Hafnium in the RCCA's and pure Zirconium coating for durability

- **Semiconductor & Electronics**
  - Tantalum, Titanium, Copper, Aluminum, Tungsten, Gold, Silver, REEs, Ruthenium, Palladium Iridium, Hafnium
  - Enormous growth in electronics (Semiconductor, Flexible, Wearable, Printed)
  - Interconnect roadmap

- **On-Shore & Offshore Wind**
  - Copper loadings per MW are 3x higher onshore, and 8x higher offshore than convention grid, with lots of Zinc used to weather coat the blades leading edge.
  - Copper foil demand growing from EV's and LFP chemistry LiB's. Uses Iridium in the production
  - NdFeB – REE's needed for huge Windmills. Hundreds of Kg per unit.

- **Solar PV**
  - Solar PV Module prices hit $210/MW before commodity price climbs to $390/MW due to price climbs in Polysilicon, Aluminum Framing, Glass, Back sheet and Silver.
  - Solar PV already consumes 13% of the global Silver supply and growing.
  - Solar Arrays use 3x the copper vs conventional grid.
  - Duck Curve, renewable curtailment, need for large scale energy storage

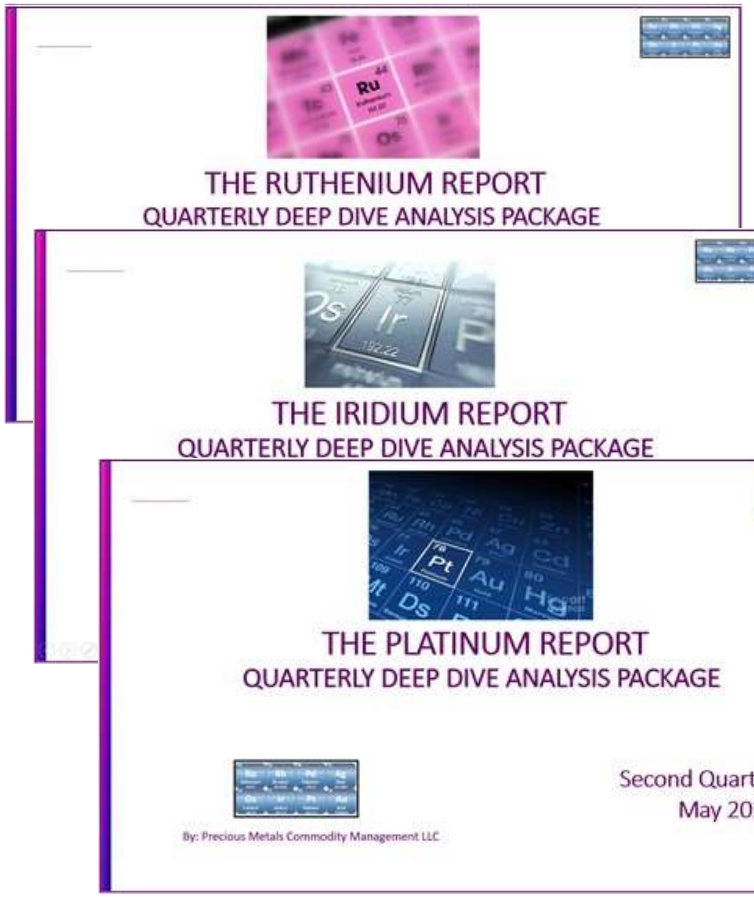
- **Hydrogen Economy**
  - Pt, Ir, and Ru are the PGM's of the future Hydrogen Economy
  - Long-Term Supply/Demand imbalance on Pt Ir and Ru
  - Duck Curve, renewable curtailment, need for large scale energy storage and Green Hydrogen and/or Green Ammonia make the most sense.
  - Duck Curve, renewable curtailment, need for large scale energy storage almost force the need for Pt Ir and Ru
  - Green Hydrogen Electrolyzers – Huge design thrifting in Iridium needed.
  - Gas-2-Power PEM Fuel Cells – Pt, Ru and Ir.
  - Transportation FCEV Pt loadings in mass is a supply concern.
  - Ruthenium critical to ammonia (NH_3), and they want to 8x that market

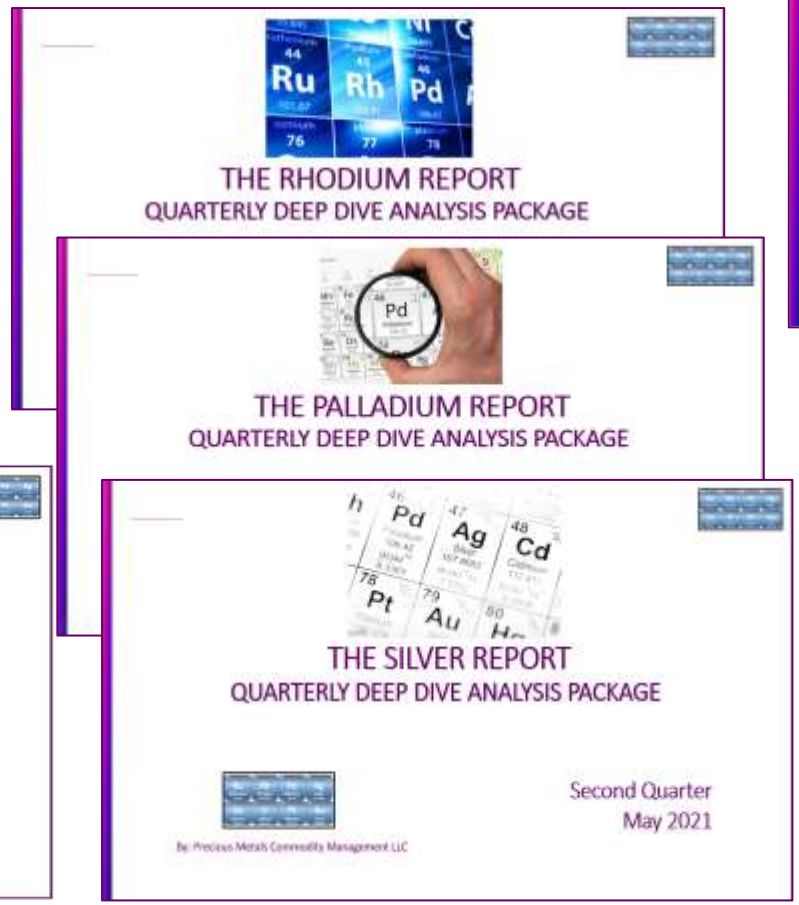
- **Rare Earth Elements**
  - 450 years of USGS Known Reserves. Anything but "Rare".
  - Dirty: 2,000 tons toxic materials for every 1mt of REE Mined & Processed
  - China ESG Issues
  - Consumption to triple by 2050
  - Home and EV Heat Exchangers and Solid Oxide Fuel Cells need REE's

- **Critical Metals Long-Range Price Forecasts**
  - Supply & Demand Fundamentals, Market Balance
  - Copper, Lithium, Cobalt, Nickel, Aluminum, Silver, PGM's, REE's
  - Mineral Reserve Constraints
  - Hard limits to Copper and Silver mining in this century

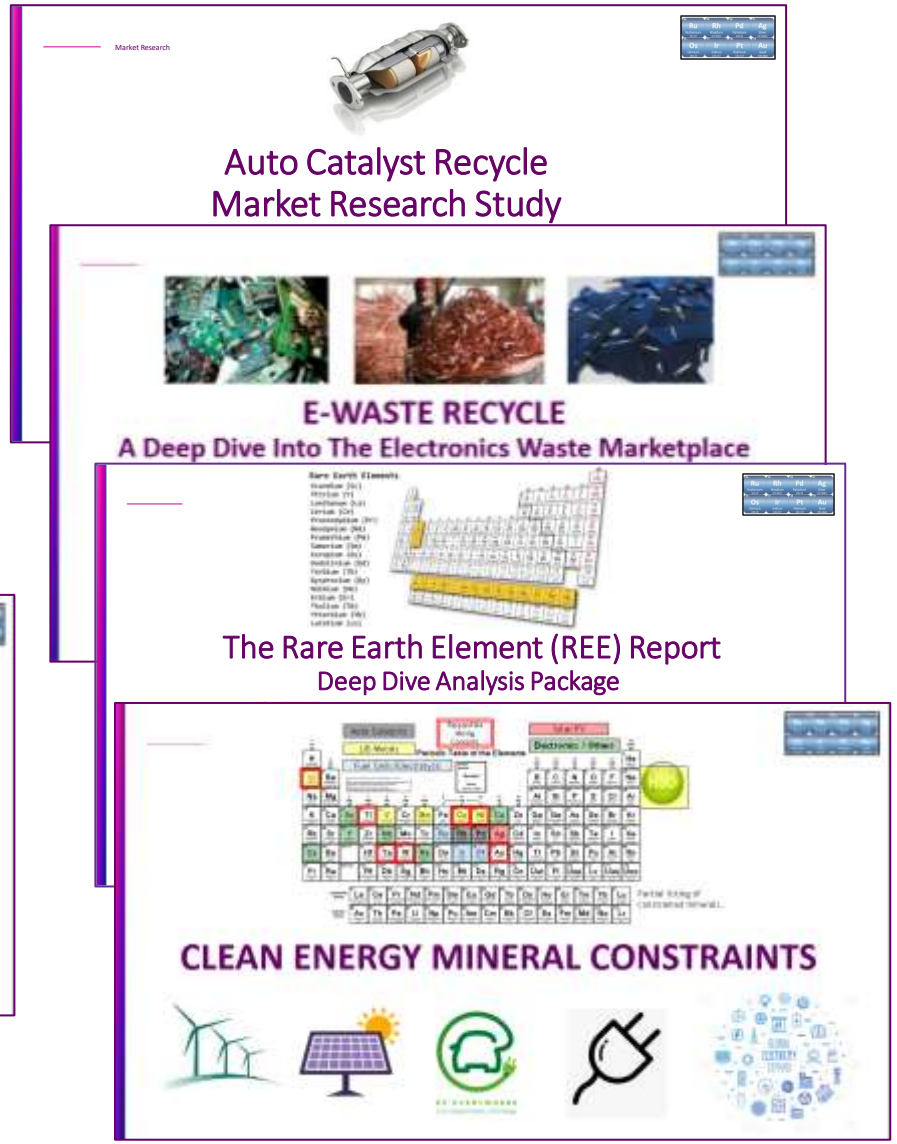
SUBSCRIPTION REPORTS

Precious Metals Bi-Annual Reports





Stand-Alone Reports



Founder: Matt Watson's Bio

20-years Precious Metals Commodity Management

- Purchased $100's of millions of industrial PM products
- Treading / Hedging / Financial Services
- Design & Process Thrifting. Reduced media sputter IDM 60^ ($1.17 to $0.46)
- Supply Chain Compression: Weeks supply from 2-years to 27-weeks.
- Extensive interface with Heraeus, JM, Tanaka, JX, Solar Applied Materials, Materion, Scotia, Furuya, DuPont, 5N.
- Active Member of IPMI and Silver Institute.

13-years
Industrial Statistician
ITT Groups & Consulting
1984 1997

17-years
Hard Disk Drive Industry
14-years with Seagate
2011

2-years
Solar PV
Flex CI GS
2013

5-years
Tanaka America
2018

Precious Metals Commodity Mgmt. LLC
Present

Industries:
- Defense Technologies
- Satellite Technologies
- Semiconductor
- Automotive
- Solar PV

Substrates:
- Engineering & Operations
- NiP Plating, CMP, Wash & AOI

Media:
- PM Thin Film PVD

Precious Metals
- $540M in Pot and Ru
- PVD Target Supply chain Management
- Trading, Leasing, hedging, PM Wet Chemistries

Supply Chain & Operations:
- Thick Film Ag Paste Screen Print
- Ruthenium PVD
- Rotary PVD PM's
- Se CVD
- Vapor Deposition
- Multiple Plating Chemistries

PM Industrial Products Bus. Dev. & R/D
- N. American R&D and Mktg.
- HDD
- Semiconductor
- Flex. Elect.
- Medical
- Wet Chem.
- New Energy

Consulting:
- Mkt. Research
- Risk Mgmt.
- Trading
- Hedging
- Forecasting
- Strategy Development

Overview: Precious Metals Commodity Management LLC

https://www.PreciousMetalsCommodityManagement.com/

Providing a Wide Range Of Consulting, Market Reports & Insights, Coupled With Supply Chain Expertise

Consulting Services

- Market Research – client specific market reports
- Supply Chain Development
- Total Cost Of Ownership Reporting Systems
- Thrifting – Mapping cost down plans
- Risk Mitigation – construction of a system/process
- Trading – demonstration, training, and facilitation
- Hedging – establishing systems to reduce market risks
- Forecasting – providing foundation to trading activities
- Strategy Development – training industrial users on how to put it all together
- Industry contacts - making the right connections

Market Reports

- Supply & Demand Fundamentals:
  - Gold, Silver, Platinum, Palladium, Rhodium, Ruthenium, Ruthenium
- Subscription Service to Quarterly Deep Dive Reports on select metals.
- Price Forecasting
- Industrial Demand Details
  - Auto Catalyst Demand
  - Fuel Cell Technologies and Electrolysis
  - Semiconductor
  - Flexible / Printed Electronics &
  - Automotive Electronics
  - Hard Disk Drive
  - Advanced Pharmaceutical Ingredients
  - Catalyst – Petrol, Ammonia, Fertilizer
  - Chlor-Alkali & Water Treatment
  - Secondary Refine Market & Capacities.

Supply Chain Expertise

- Thin Film Deposition Materials
  - PVD, ALD, CVD, MOCVD
  - Processes & Vendors
- Evaporation Materials & Precursors
- Fuel Cell Catalyst Materials
- Mesh Products
- Bonding Wire
- Solder and Brazing Materials
- Cardiovascular & Embolism Wire
- Die Attach & Thick Film Pastes
- Thick Film Resists
- Compounds
- Screen Printing
- Wet Chemistries
- Catalyst Products & Compounds
- Grains & Flakes
- Bullion, Coins, Minting Processes
- Shields, Chamber Sweeps, Scrap Recovery

News Interview & Events

[Platinum group metals demand to soar in face of biggest dilemma in history]

My ongoing mantra:

This will be the century of Clean Energy and Mineral Constraints.

Events

- **Mar'21** [Pre-PDAC Seminar Keynote]
- **Mar'21 – PV Magazine -** [Silver accounts for 10% of PV module costs]
- **May'21 Silver Institute** – [Demand growth in the Flexible & Printed Electronics]
- **June'21** [Soar Financial Interview] **–** Mineral constraints to meet the global Zero Emission Vehicle Mandates
- **June'21 –** [PGM Recovery Systems Interview] – Clean Energy Mineral Constraints
- **June'21 - IPMI Auto Catalyst & Fuel Cell Conference** –– Topics Auto Catalyst Recycle long term Demand, H_2 Economy, & Recycle
- **June'21 – Master Minds Silver** – Cu and Ag Demands & Constraints
- **July'21 – Pre-PDAC Conference Keynote** – Silver and Copper Demands & Constraints
- **Oct'21 –** [Kitco Interview]**:** Clean Energy Impacts
- **Oct'21 - IPMI Annual Conf**. – Copper/Silver Markets & Clean Energy Mineral Constraints
- **Oct21 – Kitco Podcast**– Mineral Constraints
- **Oct'21 –** [Red Cloud Oktoberfest Keynote]**: –** Copper, Silver and Gold -
- **Nov'21 – American Recyclers Association Conference –** Clean Energy and EV Minerals Demand Outlook
- **March'22 –** [Investing News Network Interview]**:** Silver Mine Supply Needs to Double, What's in Store for Prices?
- **March'22 – IPMI AutoCat & Fuel Cell Conference** – H_2 Economy & Clean Energy Mineral Constraints
- **June'22 – Silver Institute –** [White Paper: Silver Brazing and Solder Alloys]
- **June'22 -** [OreDay 2022 Keynote]: Clean Energy Mineral Constraints
- **June'22 – IPMI Annual Conference:** The H_2 Economy: Key Hurdles and Opportunities
- **July'23: Nobel6 Podcast:** [The reason we need a Large Scale Energy Storage Solution!]
- **July'23 – RedCloud:** [Cu, Ni, Zn, PGMs in the Clean Energy Transition]
- **Sept'23: NY Chapter IPMI:** Future of PGMs
- **Sept'23: Kitco Interview** – topics TBD
- **Dec'23: ICEPAG 2023** – Critical Mineral Constraints
- **Mar'24 IPMI Auto Catalyst & Fuel Cell Conference** – Topic TBD
- **July'24 IPMI Annual Conference** – Topic H_2 Economy

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