

Precious Metal Catalysts

A cornerstone for the Hydrogen Economy
and Ammonia as an Energy Vector

16.11.2022, Phoenix, Konrad Krois

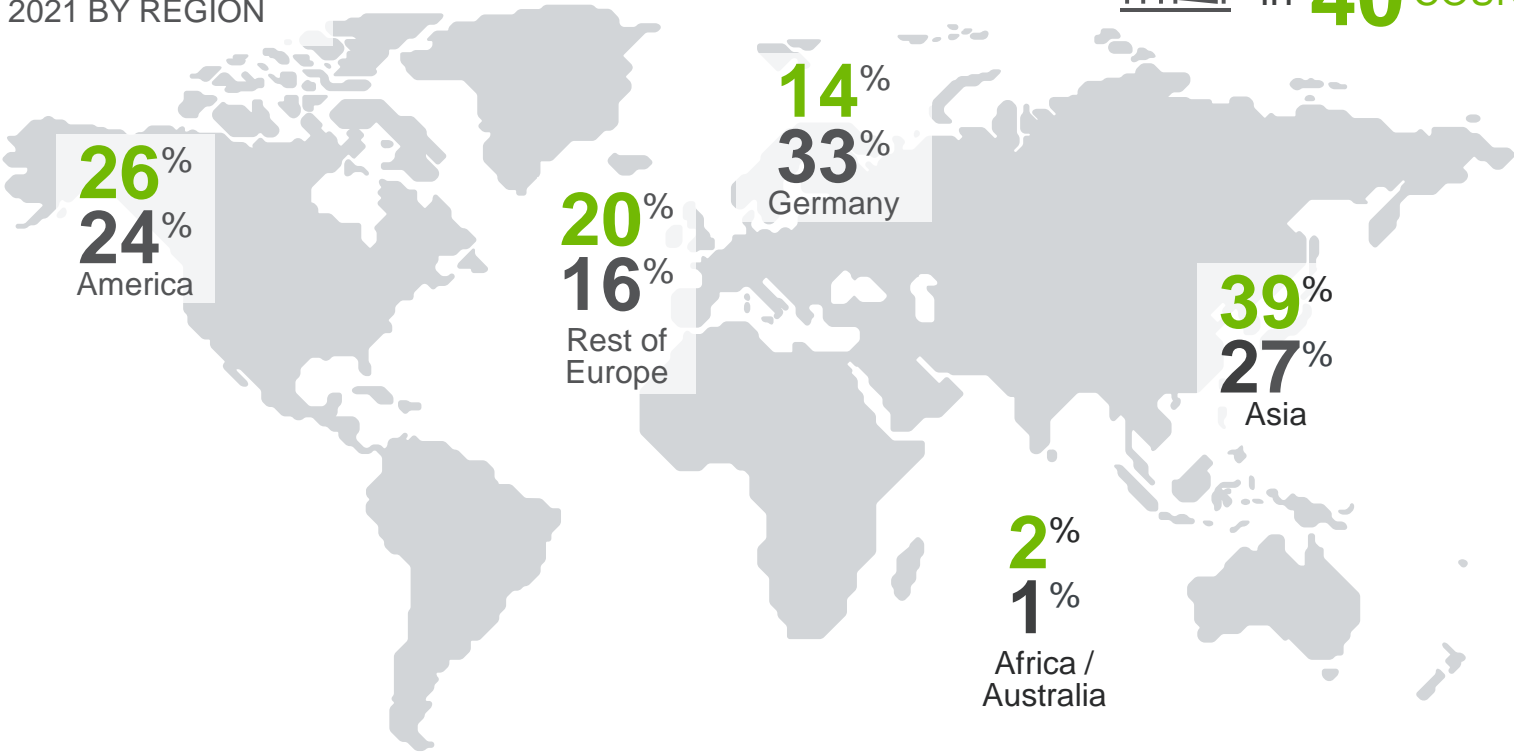
A GLOBALLY SUCCESSFUL PORTFOLIO COMPANY

REVENUE EXCL. PRECIOUS METALS

2021 BY REGION

EMPLOYEES

2021 BY REGION



More than **100**
SITES
in **40** COUNTRIES

TOTAL REVENUE
29.5 bn

7% R&D
EXPENDITURES¹

Market-oriented distribution
in **12** GLOBAL
BUSINESS
UNITS

TOP 10 FAMILY-
OWNED COMPANIES
in Germany

Listed in
FORTUNE
GLOBAL **500**

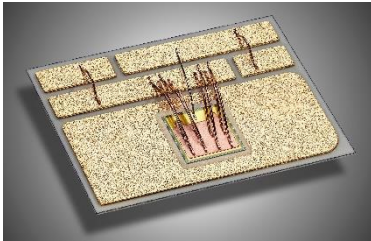
EMPLOYEES²
16,200

¹ based on revenues excl. Precious Metals ² incl. contract employees

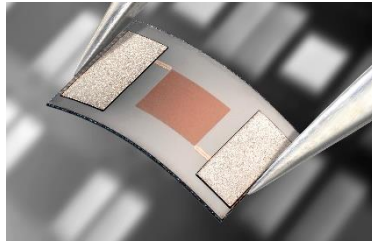
BUSINESS PORTFOLIO – LEADING IN GLOBAL MARKETS



**Heraeus
Precious
Metals**



**Heraeus
Electronics**



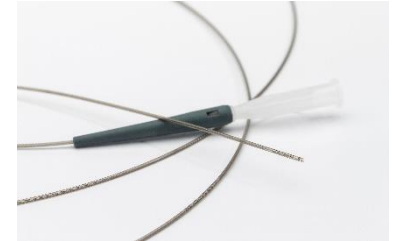
**Heraeus
Nexensos**



**Heraeus
Epurio**



**Heraeus
Medical**



**Heraeus
Medical
Components**



**Heraeus
Conamic**



**Heraeus
Comvance**



**Heraeus
Noblelight**



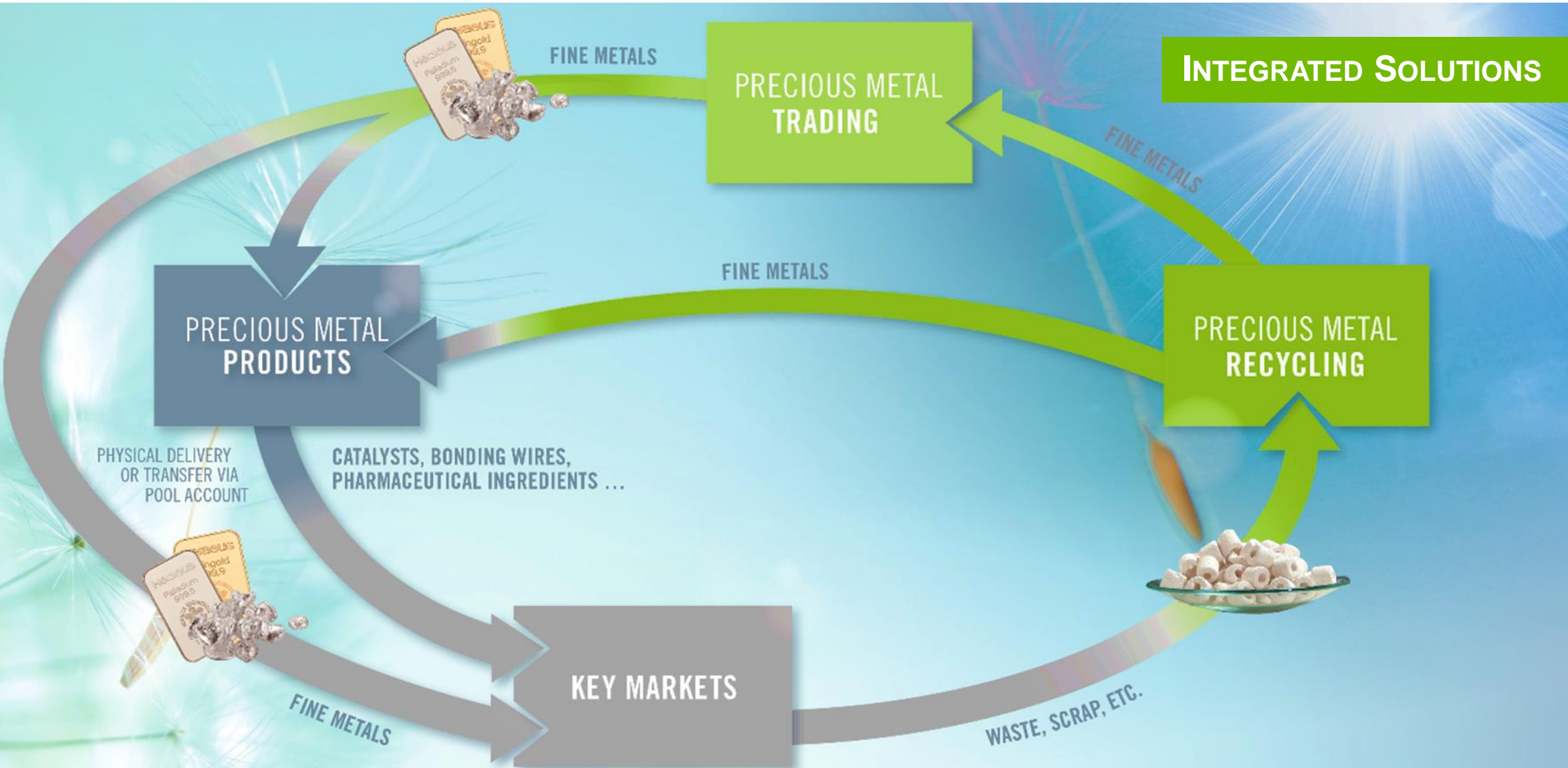
**Heraeus
Electro-Nite**



**Heraeus
Photovoltaics**



**Heraeus
Norwood
Medical**



Gold	Silver	Platinum	Palladium	Rhodium	Ruthenium	Iridium	Osmium	Rhenium (SEMI-PRECIOUS METAL)
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OUR **PRECIOUS METALS PRODUCTS** CONTRIBUTE TO VARIOUS INDUSTRIES LIKE HEALTH, AUTOMOTIVE, ELECTRONICS AND LUXURY

Argor-Heraeus



- Semi-finished products for
- luxury watch
- jewellery industry

Functional Materials



- Contact Products
- PGM-Fabrications
- Semi-finished materials
- High-tech materials and compounds

Pharmaceutical Ingredients



- Generic APIs
- Custom manufacturing
- Quality and regulatory services

Precious Coatings



- PM compounds for the decoration of glass, ceramics, aluminum and stainless steel
- Resinates for industrial functional thin film coatings

OUR **PRECIOUS METALS CHEMICALS** SECURE SUSTAINABILITY IN THE FIELDS OF ENVIRONMENT, ENERGY, HEALTH AND NUTRITION

Chemical Products



- Precious Metals Compounds
- Homogeneous catalysts

Catalytic Gauzes



- Ammonia Oxidation
- Hydrogen Cyanide
- N₂O Abatement

Chemical Catalysts



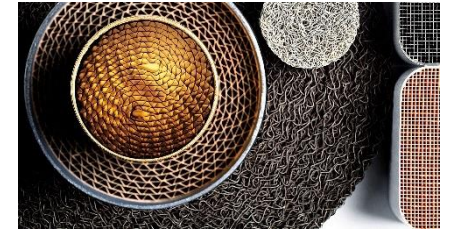
- Production of Chemicals
- Gas Purification
- Special Catalysts

Hydrogen Systems



- PEM Fuel Cell Catalysts
- PEM Electrolyzer Catalysts

Emission Catalysts

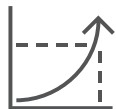


- Small Engine Applications
- System Integrators
- Powersport Applications

PRECIOUS METAL CATALYSTS IN A NUTSHELL: PERFECTLY SUITED FOR OXIDATION AND HYDROGENATION REACTIONS

Characteristics

Activity / Selectivity



Properties

- Incompletely filled d-orbital, unpaired d-electrons, ...
→ easy dissociative adsorption of O_2 and H_2
- change in d-electron 'density' of small clusters
→ tailoring Selectivity, e.g. by the electronegativity of neighboring atoms

Stability



- Chemical Stability
 - Low leaching from Acids and Bases
- Thermal Stability
 - high melting points
 - limited (bulk) oxide formation
 - Low particle migration and sintering

Morphology



- highly dispersed nano-scale particles
- high surface area supports

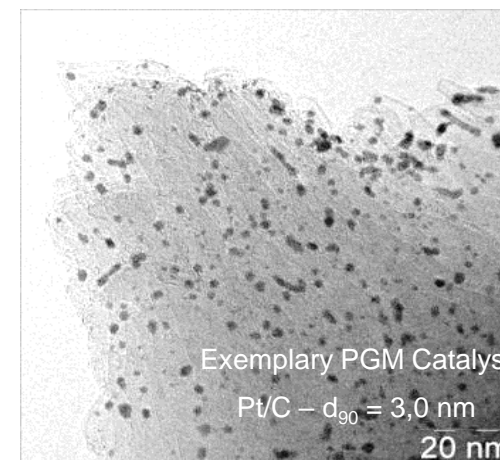
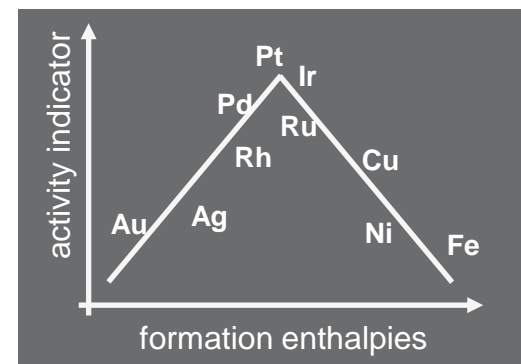
Application

Precious metal catalysts are very well suited for oxidation and hydrogenation reactions

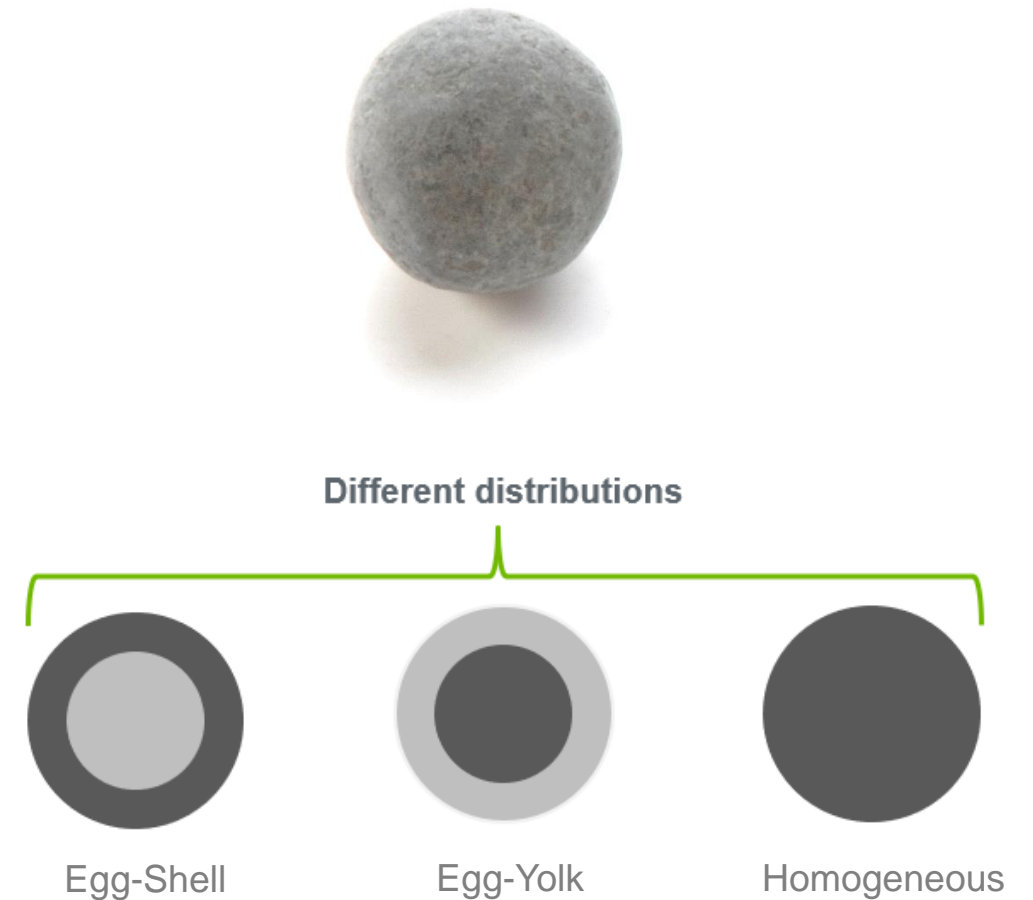
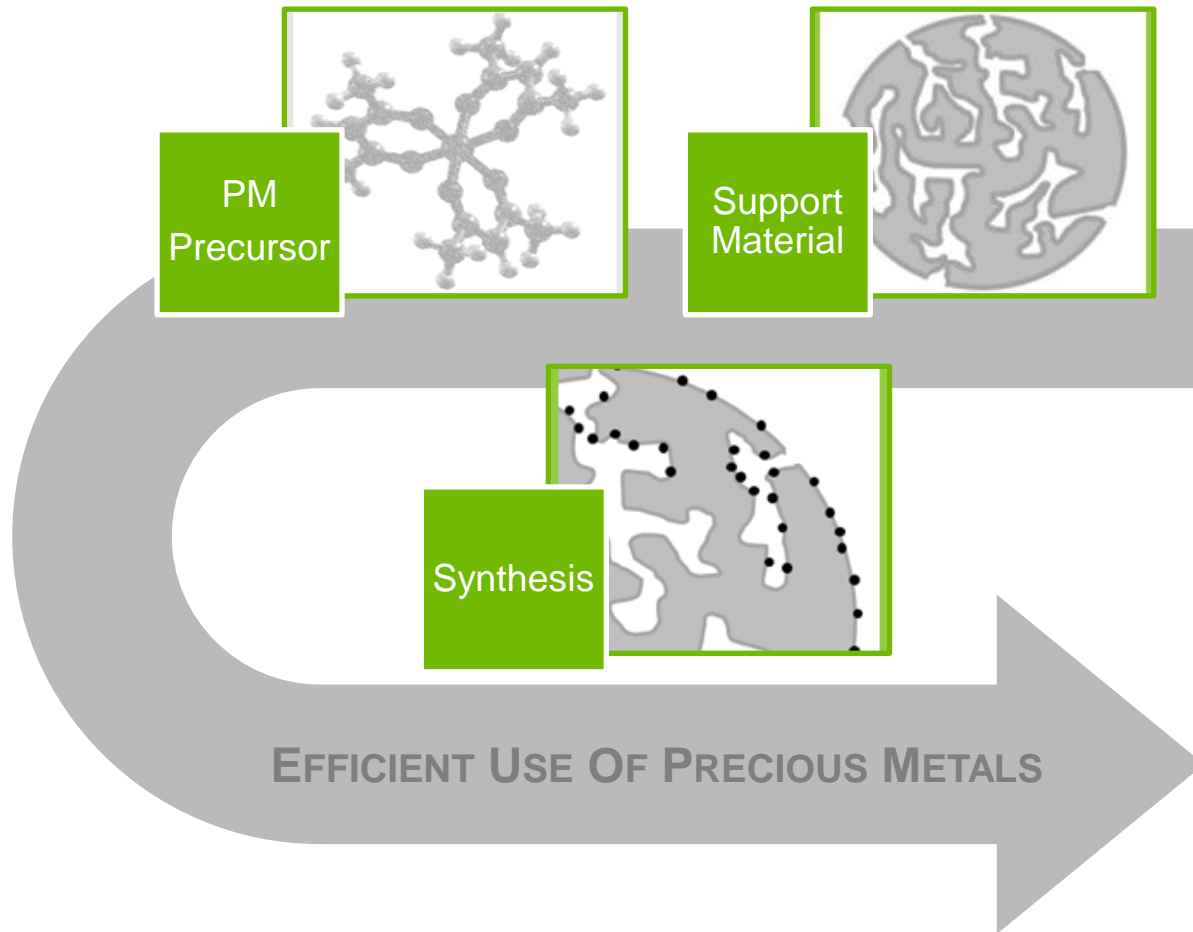
Total oxidation and full reduction reactions are especially well performed.

Their stability makes them ideal electrocatalysts

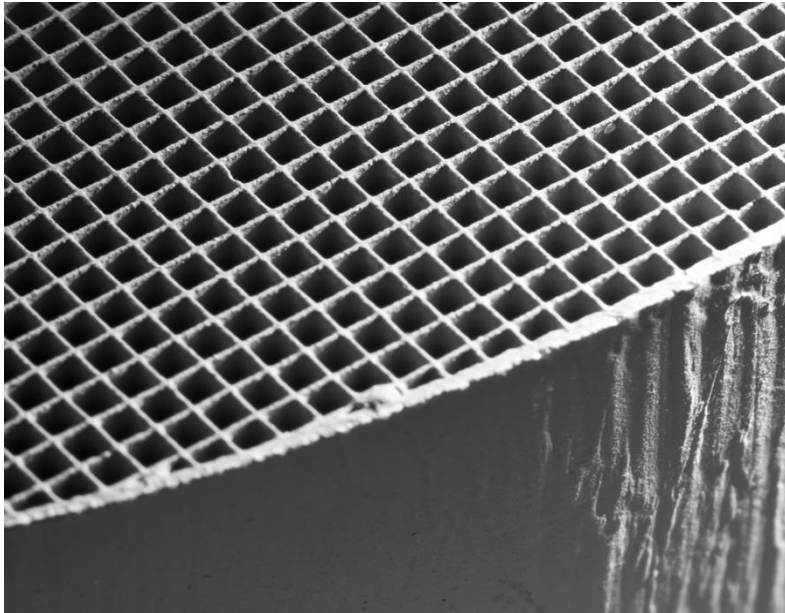
For selective oxidation or reduction reactions additional dopants may be necessary!



BULK CATALYST MANUFACTURING: SPECIFICALLY TAILORED PRODUCTS



HERAPUR® CATALYST SHAPES



Coated Honeycombs
... and other specialty substrates.

... ceramic or metal ...



Catalyst Bulk Material

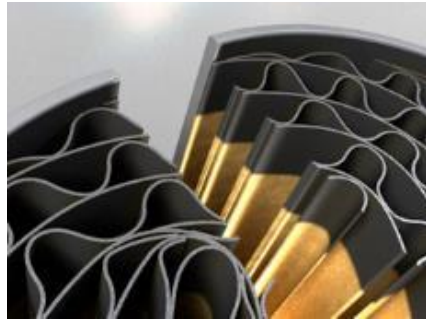
... various materials and shapes ...



Catalyst Powders

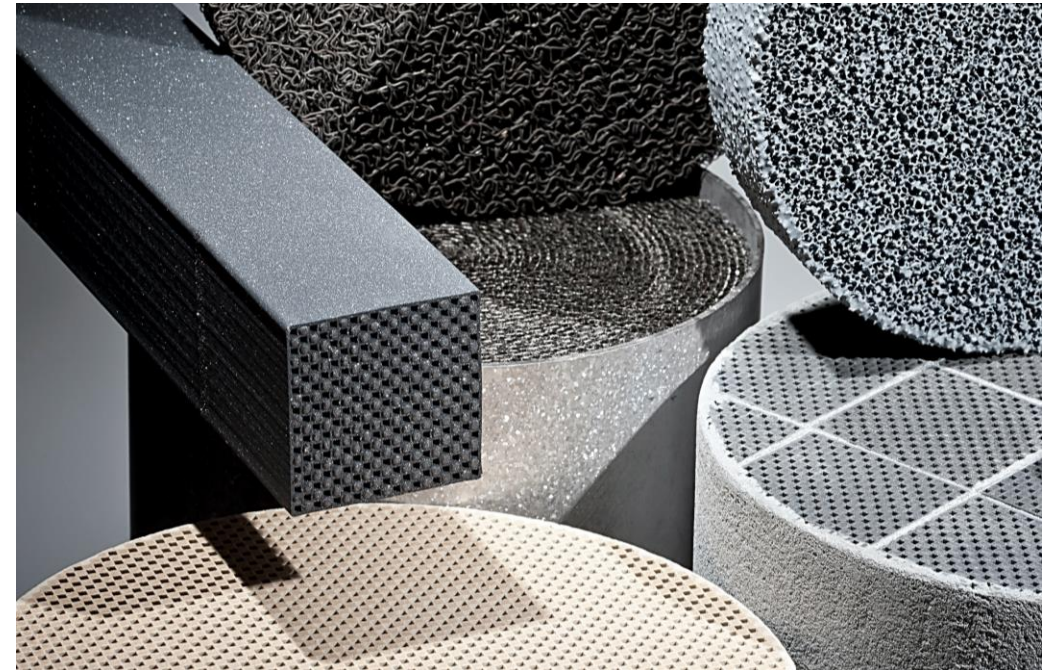
... on metal oxides or activated carbon ...

HERAPUR® COATED CATALYSTS



Heraeus Precious Metals has decades of experience in both Process and Emission Catalysis.

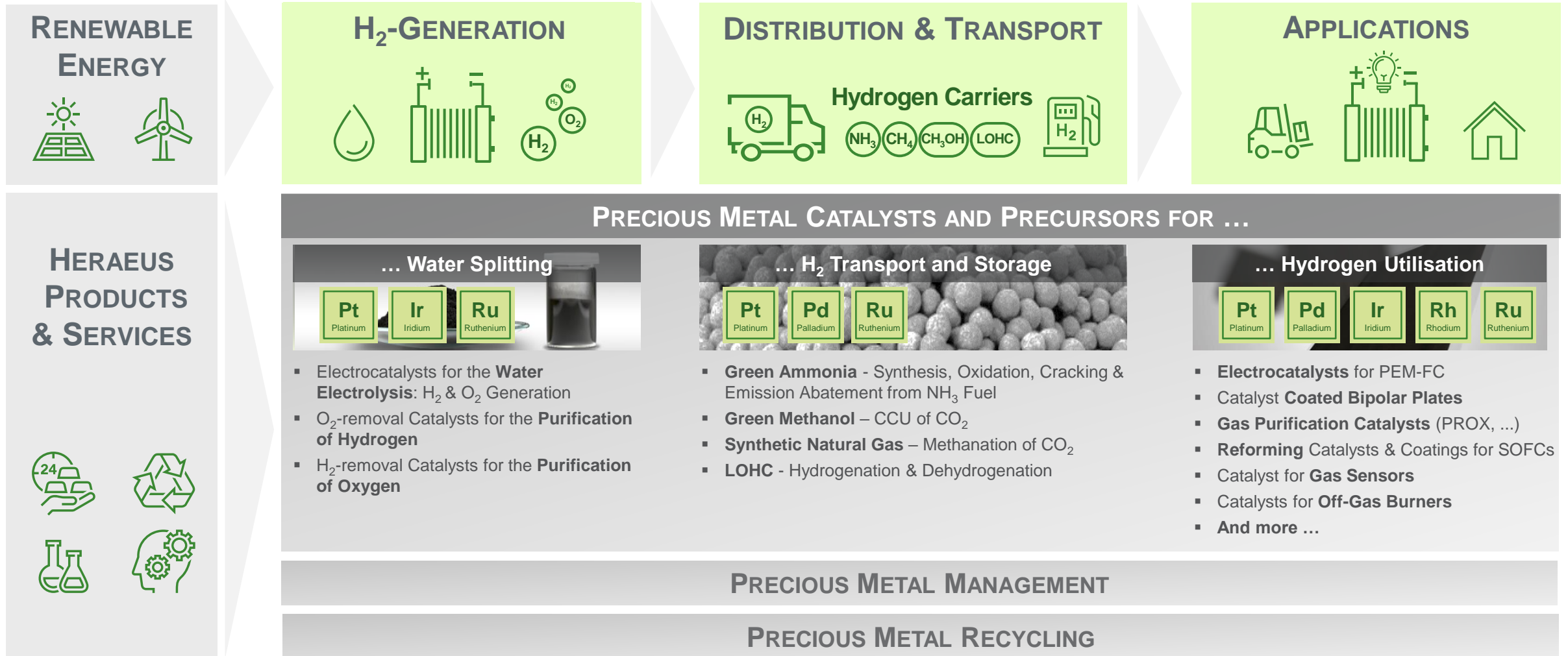
We are an experienced partner in realizing catalytic coatings also on complex support geometries - tailored to your needs.



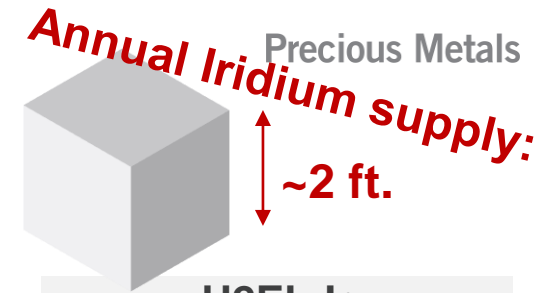
The background of the slide is a deep blue gradient. On the right side, there is a dense cluster of translucent, blue-tinted bubbles of various sizes, some of which are larger and more prominent than others. These bubbles appear to be rising or floating, creating a sense of movement. In the bottom left corner, there is a solid green rectangular box that serves as a background for the title text.

THE HYDROGEN ECONOMY

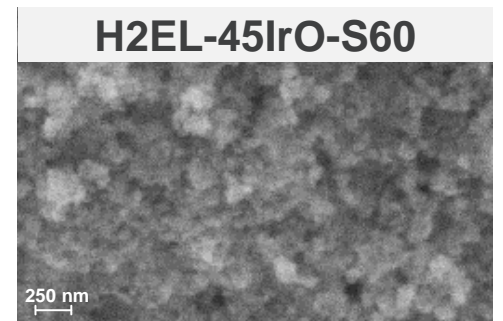
PRECIOUS METALS CATALYSTS IN **THE HYDROGEN ECONOMY**



HERAEUS PRODUCTS SOLUTIONS FOR PEM ELECTROLYSIS

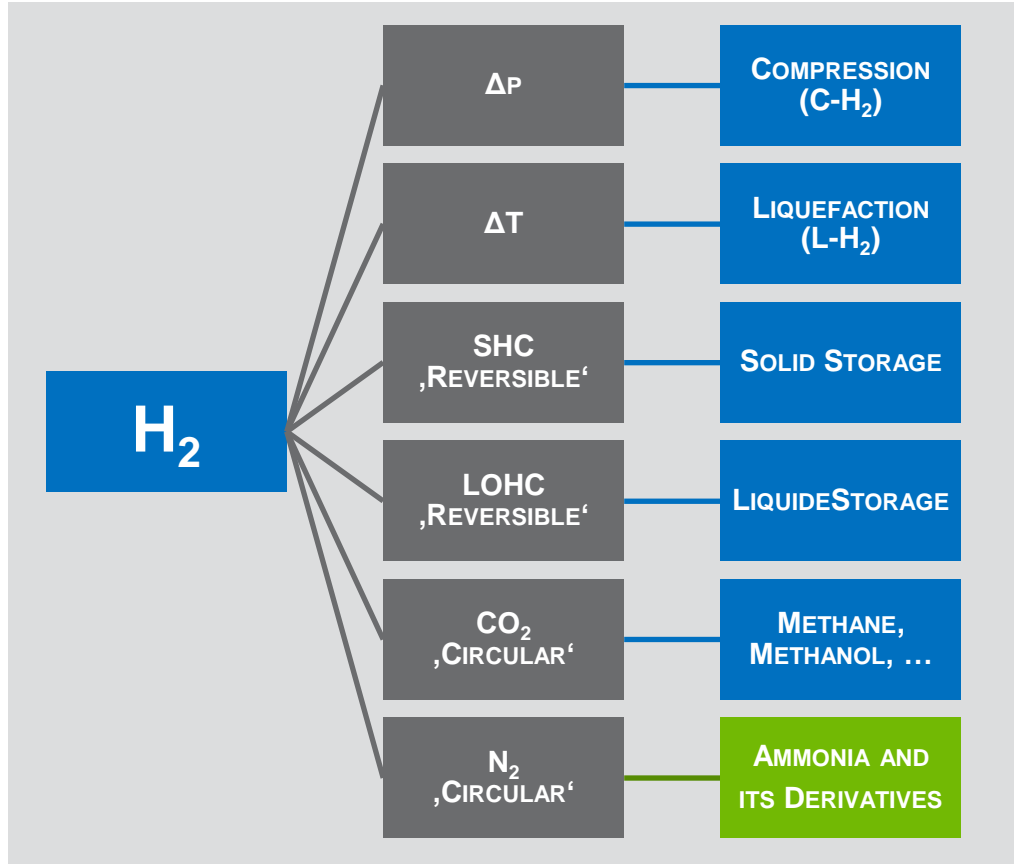


CATALYST	DETAILS	BENEFIT FOR THE CUSTOMER
H2EL-Ir	Ir black, 100 wt.-% Ir	Established product, high metal purity
H2EL-IrO	IrO ₂ , 80 to 86 wt.-% Ir	High stability & efficiency & surface area (> 180 m²/g) → increased performance at 50% loading
H2EL-xxIrO-S	IrO(OH) _x on support, 10 to 50 wt.-% Ir	Next Gen Catalyst for industrialization of PEM water electrolysis → decrease of Ir loading to < 0.4 g/kW feasible
H2EL-xxIrRu	Ir-Ru Mixoxide, 80 to 10 wt.-% Ir	R&D system for low Ir loading → future alternative

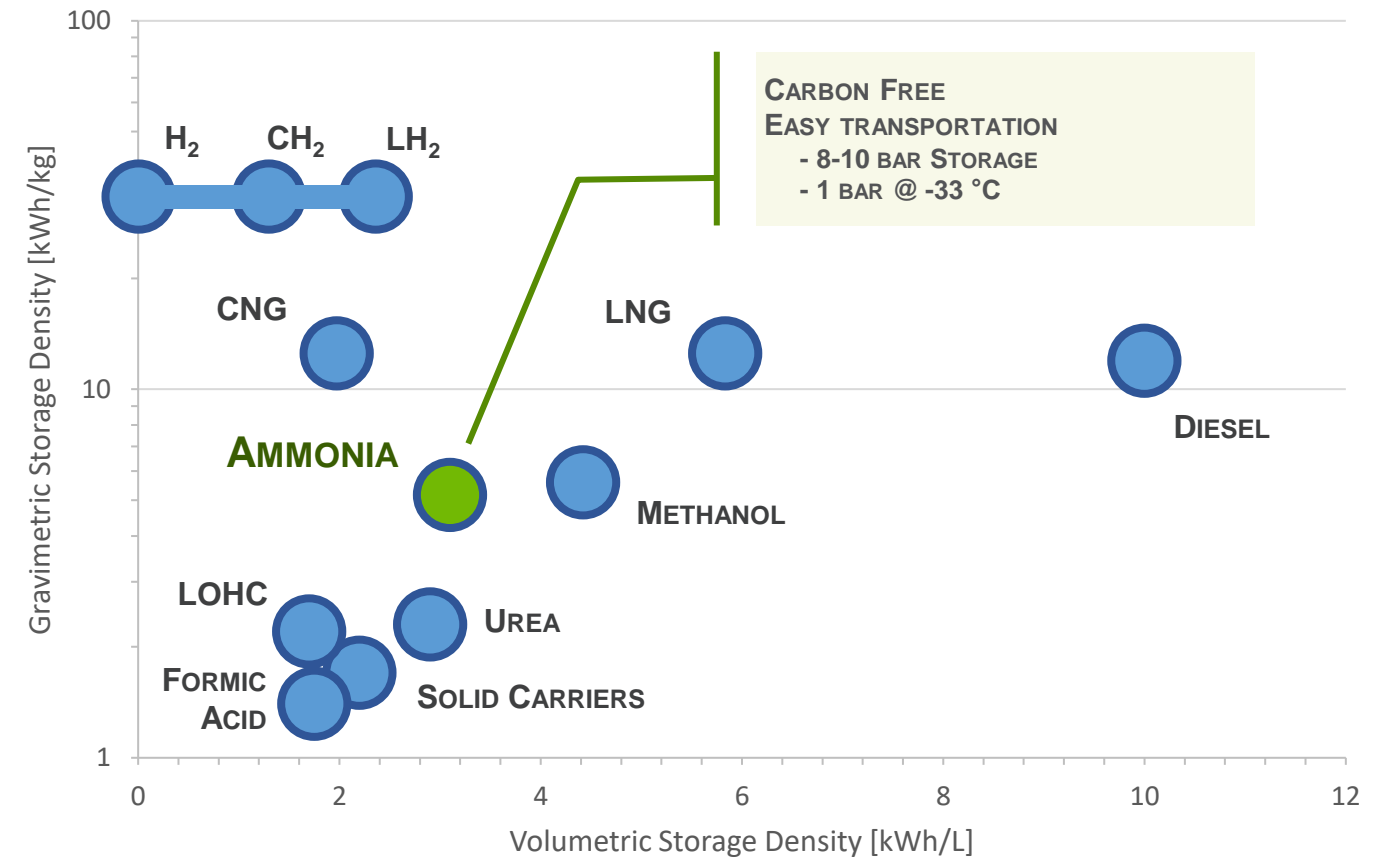


HYDROGEN STORAGE – GREEN AMMONIA

HYDROGEN STORAGE OPTIONS



STORAGE DENSITIES

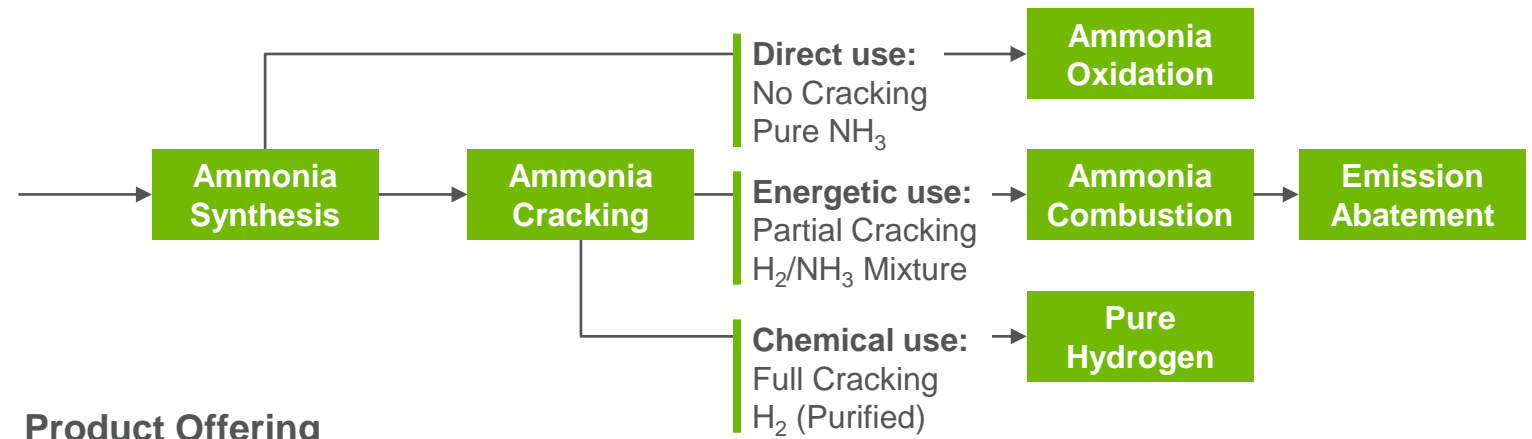


Data Sources:
1) P. M. Aziz, A. TriWijayanta, A. B. D. Nandiyanto, Energies 2020, 13, 3062
2) T. Aakko-Saksa, C. Cook, J. Kiviahio, T. Repo, J. of Power Sources 2018 396, 803-823.
3) J. Adolf et.al., Shell LNG Study - Facts, Trends and Perspectives, 2019

PRECIOUS METAL CATALYSTS ARE APPLIED THROUGHOUT THE WHOLE AMMONIA VALUE CHAIN



Precious Metal Application



Product Offering



Chemical Products

- Ruthenium Salts
- KAA Process, ...



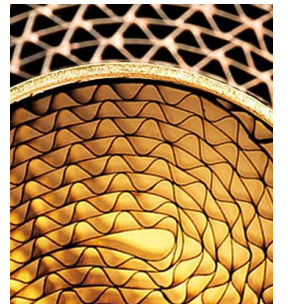
Catalytic Gauzes

- FTC Gauzes
- Ostwald process



Process Catalysts

- Bulk Catalysts
- Ammonia Cracking



Emission Catalysts

- Coated Substrates
- N₂O Abatement

HERAPUR® CATALYSTS – AMMONIA CRACKING

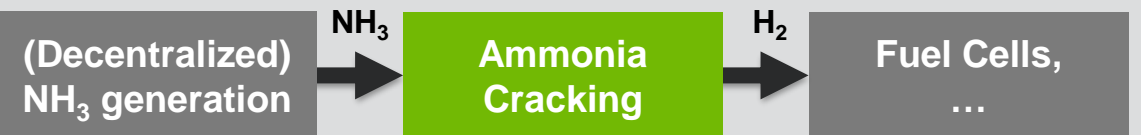
HeraPur® K-045-Series



Physical Data	Value
Catalyst	Ru / Al ₂ O ₃
Standard Load	0,5 – 2,0 wt.-% Ru
Shape	Spherical
Standard Size	2,2 - 2,5 mm

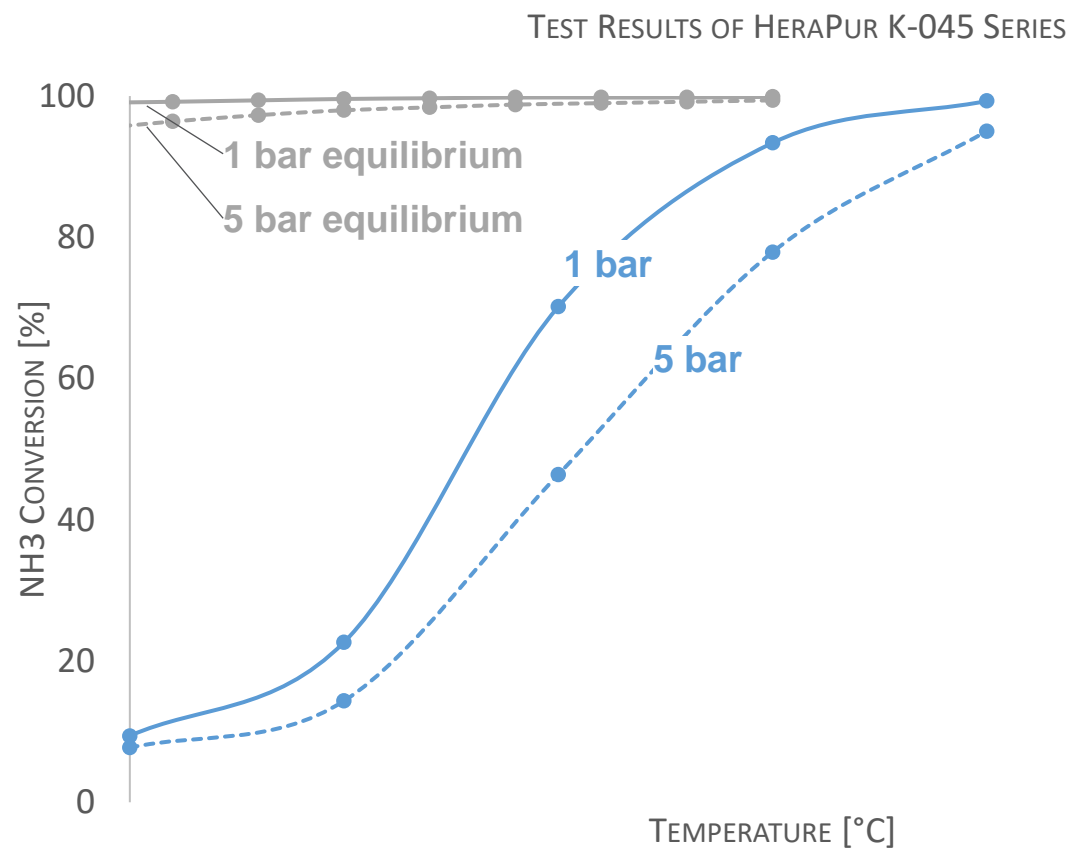
NH₃44
Ru
Loading

HERAPUR® RU-BASED CRACKING CATALYSTS



- Precious metal catalysts as efficient and durable solution for Hydrogen generation by Ammonia cracking.
- Application at lower temperatures and dynamic operation conditions possible.
- Variable support sizes to use in larger or smaller reactor tubes.
- Additional PGM or base metal dopants available.
- **Fast and flexible prototyping with customized solutions available**
- **Results from proprietary test programme**

TEST RESULTS ON STANDARD CATALYSTS



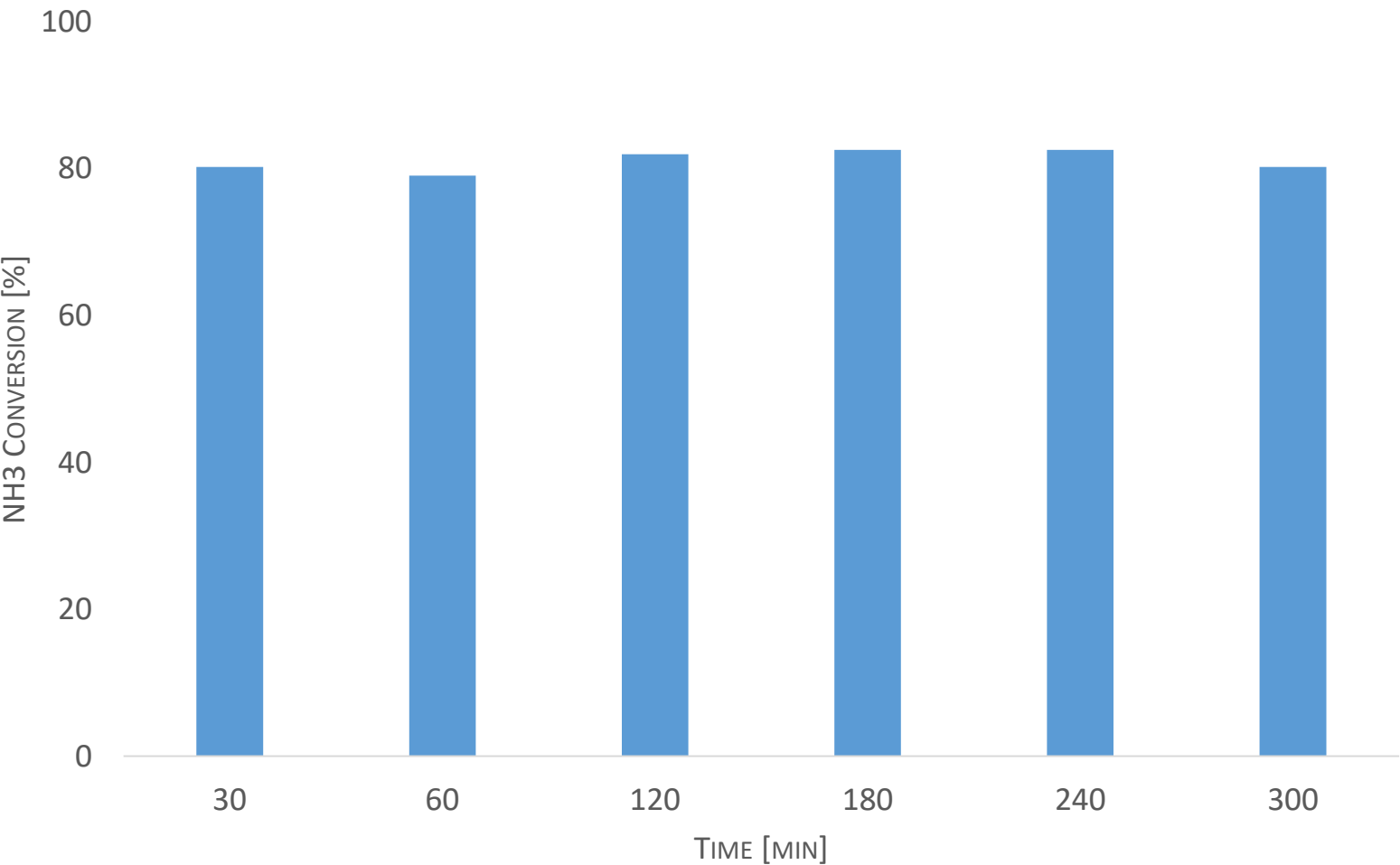
HeraPur® K-045 Series



Physical Data	Value
Catalyst	Ru / Al ₂ O ₃
PGM Load	0,5 – 2,0 wt.-% Ru

LIMITATIONS BY THE THERMODYNAMIC EQUILIBRIUM

TEST RESULTS ON STANDARD CATALYSTS



HeraPur® K-045 Series



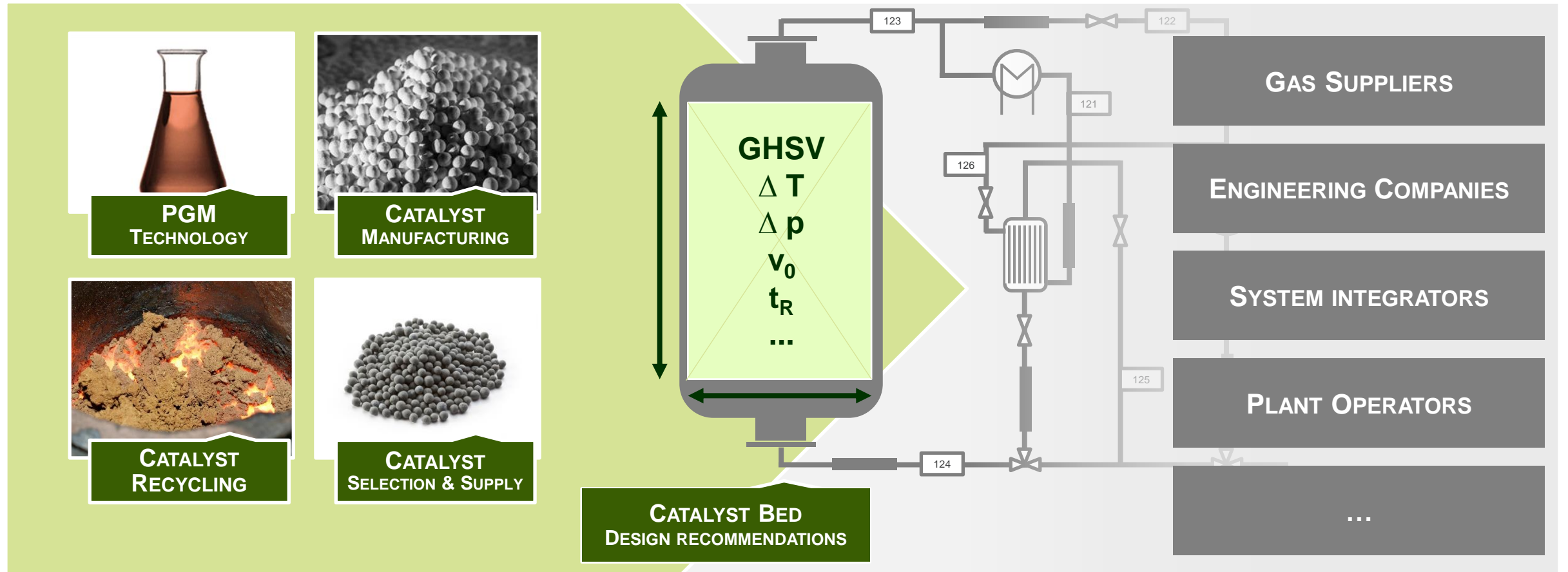
Physical Data	Value
Catalyst	Ru / Al ₂ O ₃
PGM Load	0,5 – 2,0 wt.-% Ru

DEGREENING TEST
@ CONSTANT TEMPERATURE, 5 BAR

BULK CATALYSTS: DESIGN, MANUFACTURING & VALUE CHAIN

HERAEUS VALUE ...

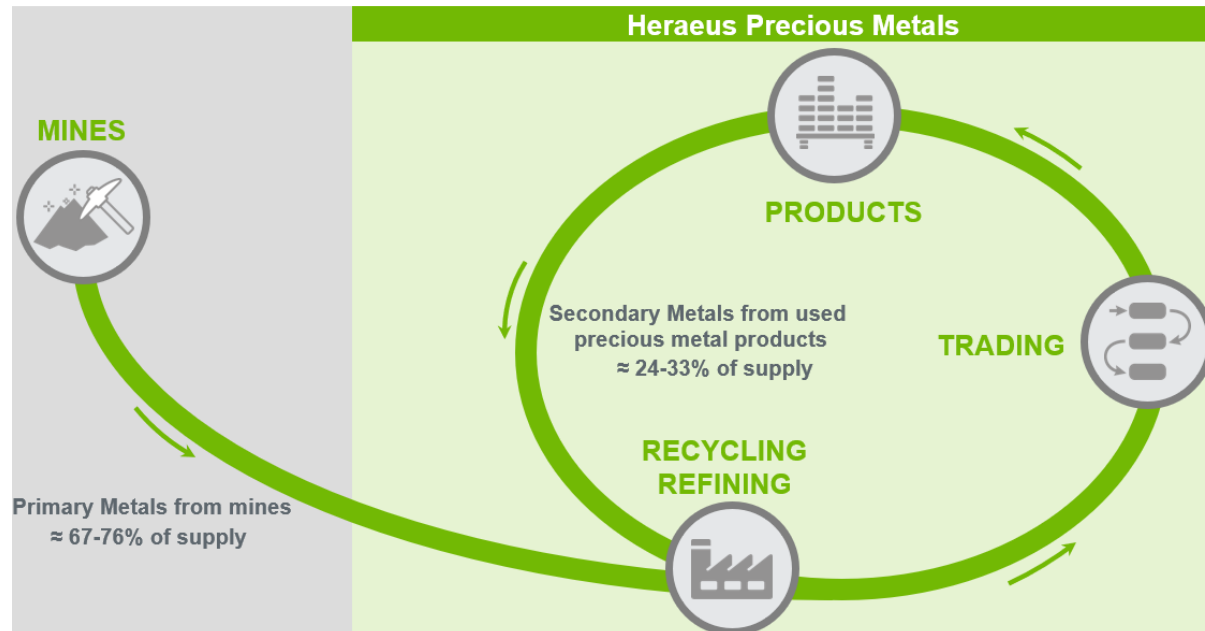
... TO OUR CUSTOMERS



WHILE LIMITED AVAILABLE, RECYCLED PRECIOUS METALS HAVE MASSIVE CO₂ SAVING POTENTIAL

Precious Metal Sources and Availability

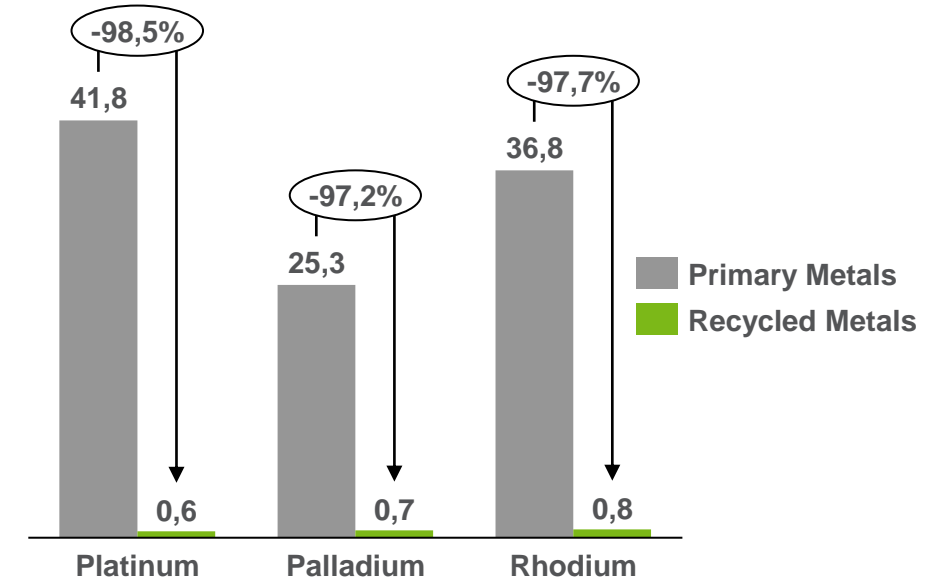
- Precious metals can either originate from mines (primary metals) or from recycling of used precious metal products (secondary metals).



- Primary metals account for roughly 67-76% of annual precious metal (Pt, Pd, Rh) supply while only 24-33% of supply is coming from recycled metals.
- Recycled metals can only cover a fraction of total PGM demand.

Carbon Footprint of Precious Metals (LCA Study)

- Carbon Footprint of primary vs. recycled precious metals in kg CO₂-eq per gram precious metal:

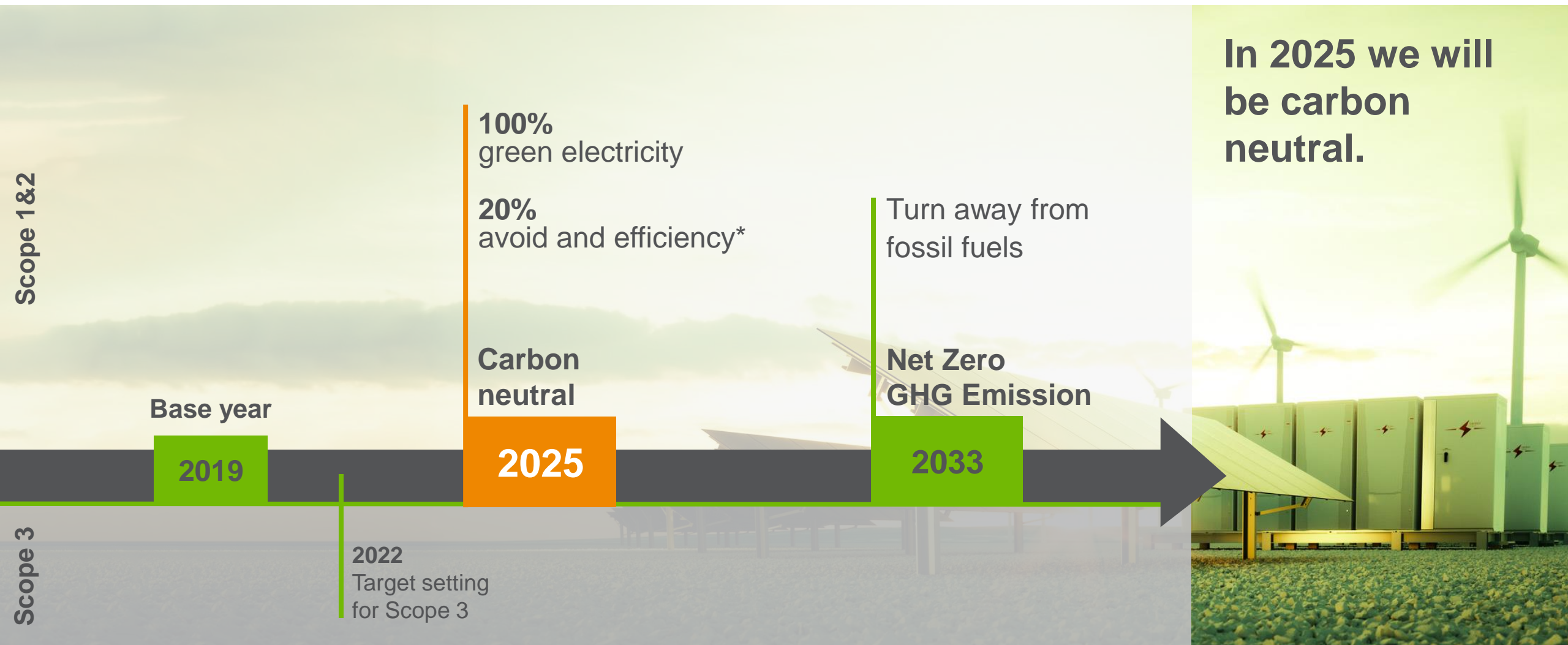


Source: [International Platinum Group Metals Association](#)



- Recycled Metals provide a massive CO₂ saving potential compared to primary metals by reducing the carbon footprint up to 98.5%!

OUR DECARBONIZATION ROADMAP



* Savings refer to our emissions and set-up in 2019

- Precious Metals are used throughout the Hydrogen Value chain
- Heraeus Precious Metals offers a Full Service on every Aspect of Precious Metals
- *state-of-the-art* cracking catalysts readily available off the shelf or as tailor-made solutions
- Recycled Precious Metals enable to dramatically lower scope 3 carbon footprint
- We are actively looking for Partnerships to support Endeavours in the Hydrogen Economy

**COMMITTED TO YOUR
PRECIOUS NEEDS!**



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LEARN MORE ABOUT THE TRENDS IN THE PRECIOUS METALS MARKET

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