ARE CRITICAL MINERALS FUELING OR FAILING THE FUTURE OF GREEN HYDROGEN?

Abhirabh Basu
Senior Analyst

PEAK PHOSPHATE CONCERNS

Early warnings

Experts predicted phosphate production would peak in the early 2010s and decline, despite rising demand.

- Critical to food security
- Finite resource
- Concentrated supply

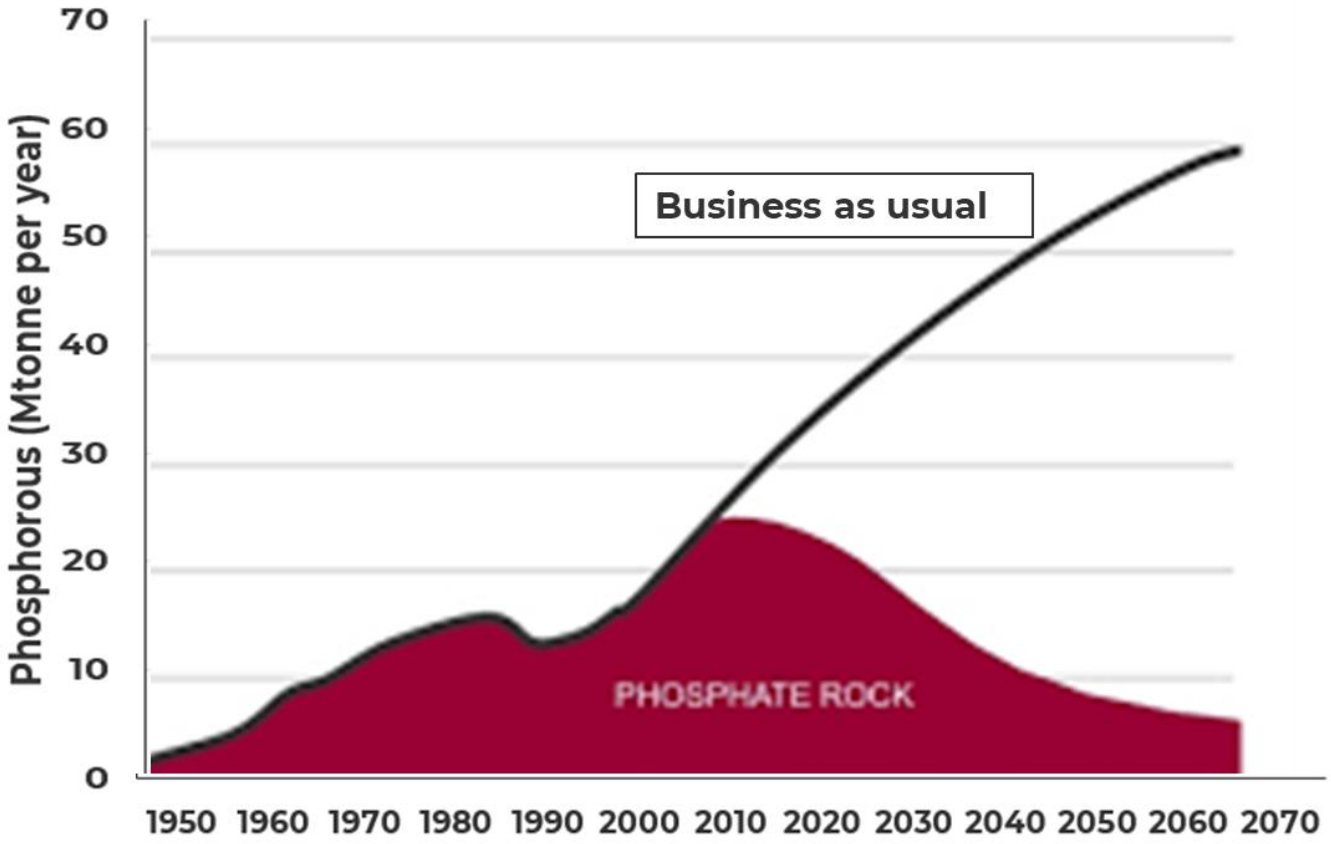


Image source: Institute for Sustainable Future

AGENDA

01 **Green hydrogen**

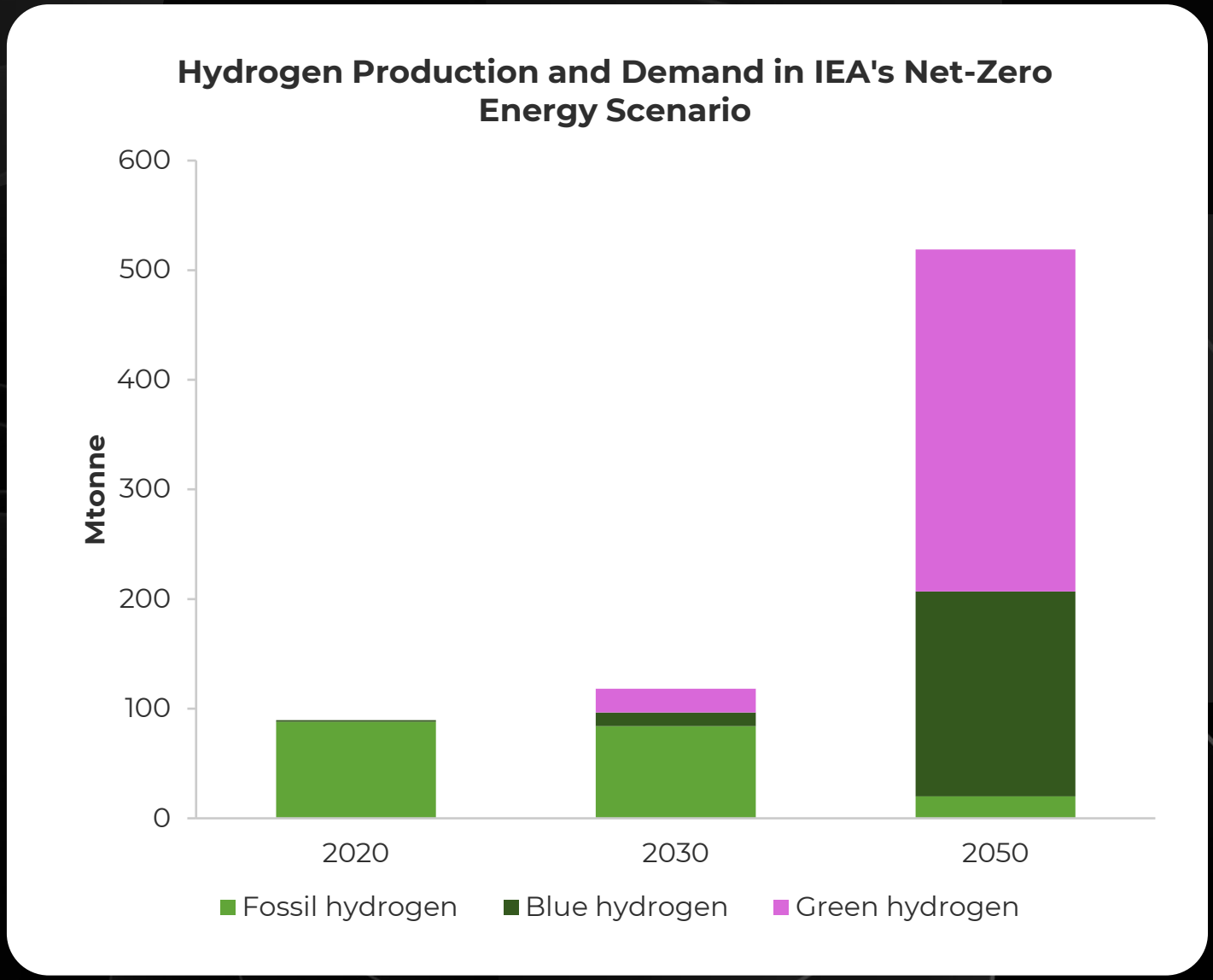
02 Lux’s Raw Materials Criticality Framework

03 Innovation strategies

04 Key takeaways

HYDROGEN DEMAND

Water electrolysis will play a crucial role in the adoption of hydrogen in the IEA’s Net Zero Energy Scenario



Source:: Lux Research

MANUFACTURING SCALE-UP NOT ON COURSE FOR 2030

High production costs cast doubt on future projections

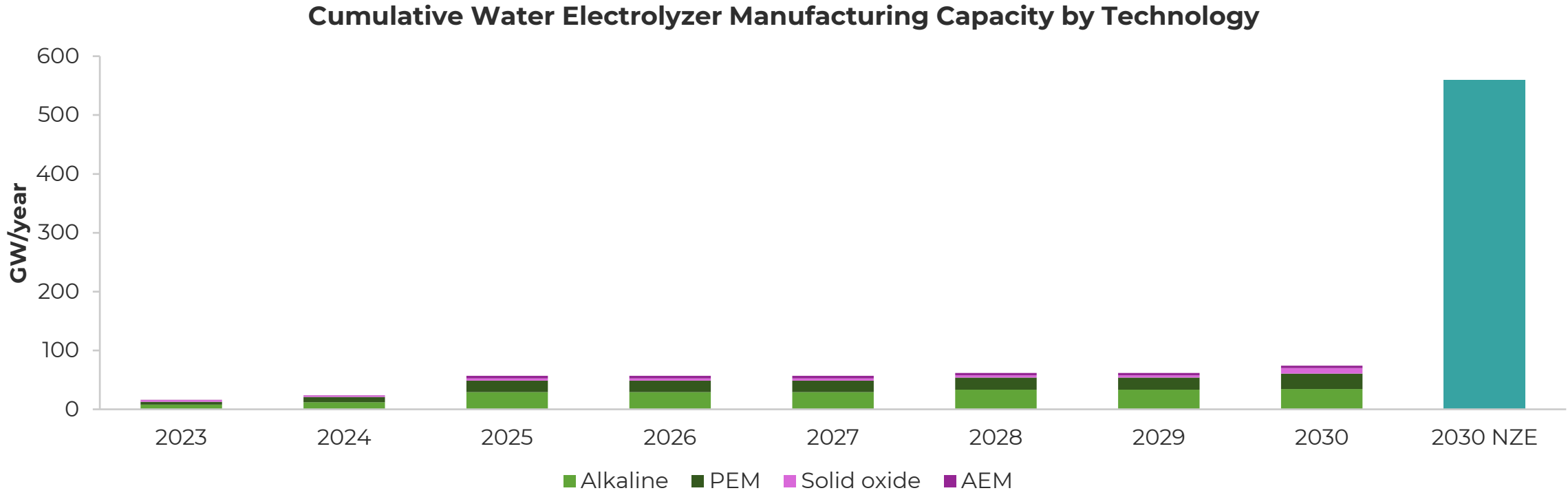
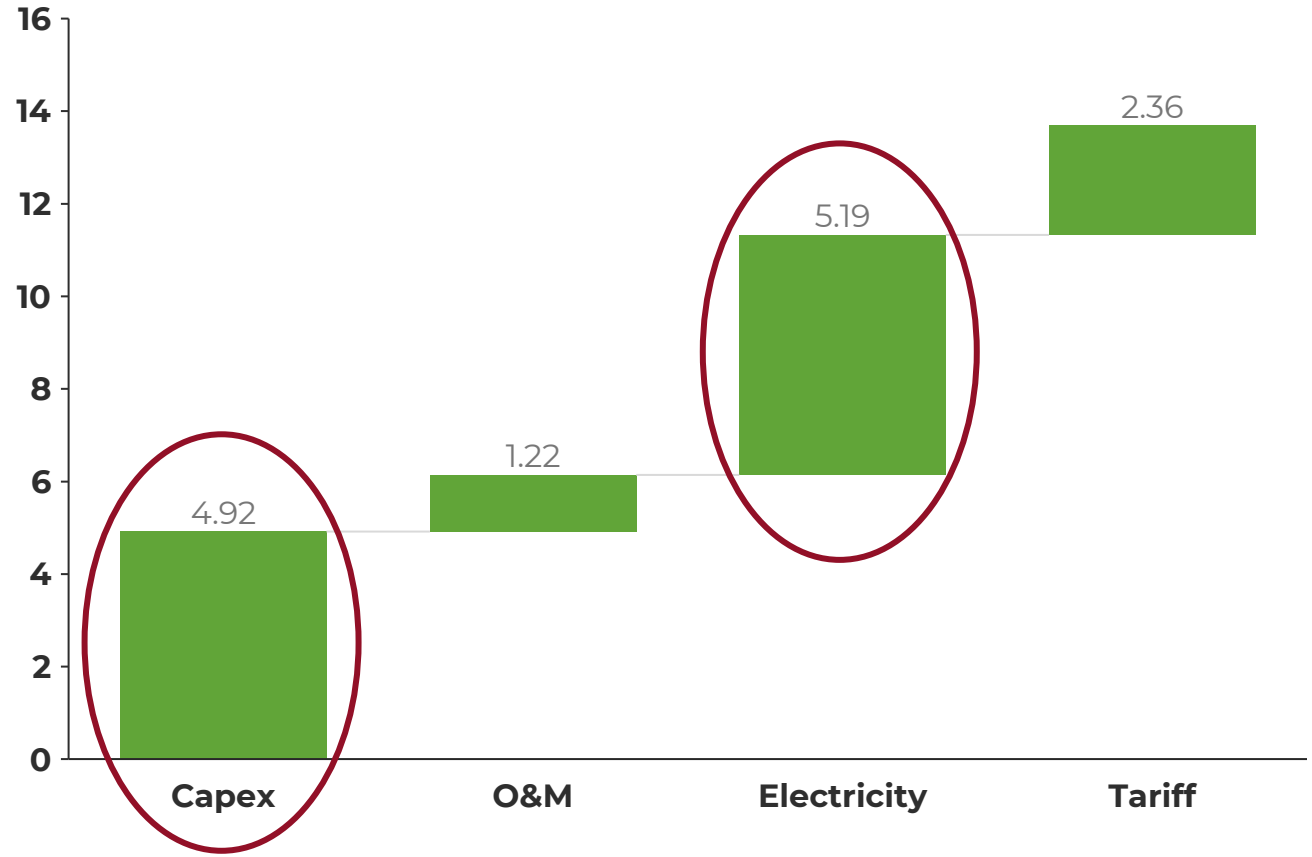


Image source: Lux Research 2023 and IEA Hydrogen

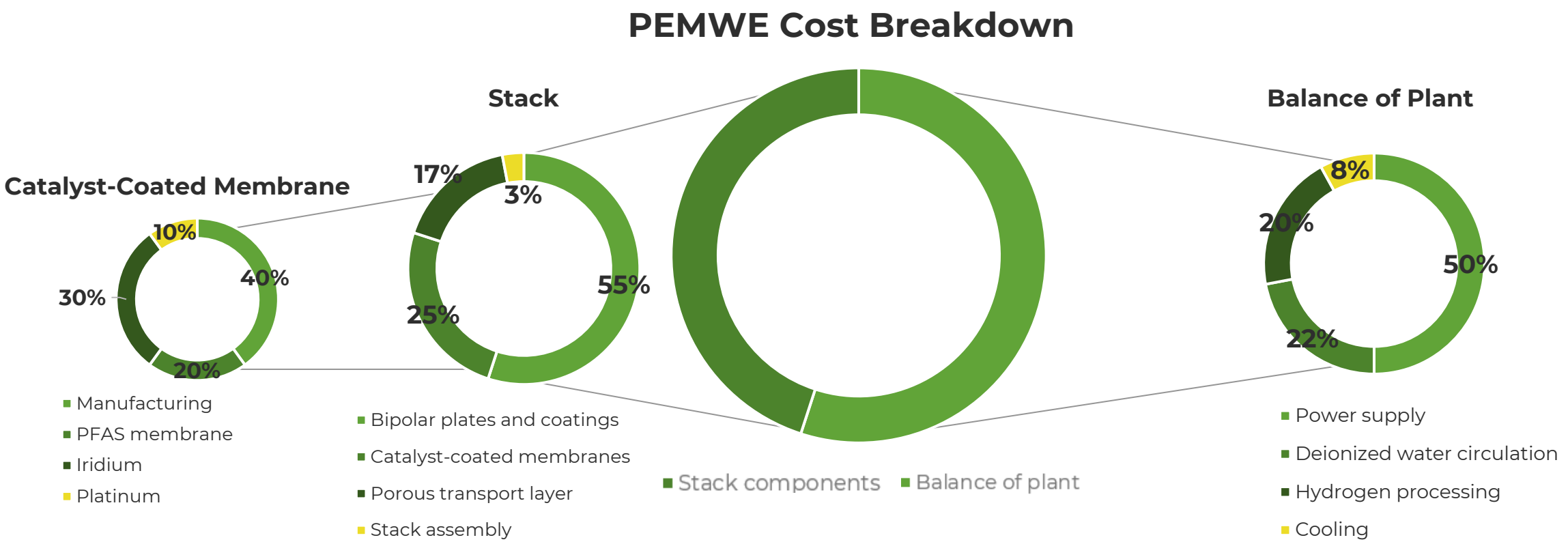
GREEN H_2 AT EUR 14/KG

Shortages in raw materials, monopolized supply chains, and volatile pricing for critical components further increase production costs.



Nominal levelized cost of hydrogen for a base case of 100 MW. The unit capex is EUR 3,050/kW, the electricity consumption is 56 kWh/kg, the price of electricity is EUR 75/MWh, the weighted average cost is 9.5%, and the full-load hours are 4,800 h. Results adapted from TNO. Stack replacement costs were included in O&M, and grid and hydrogen network tariffs were combined.

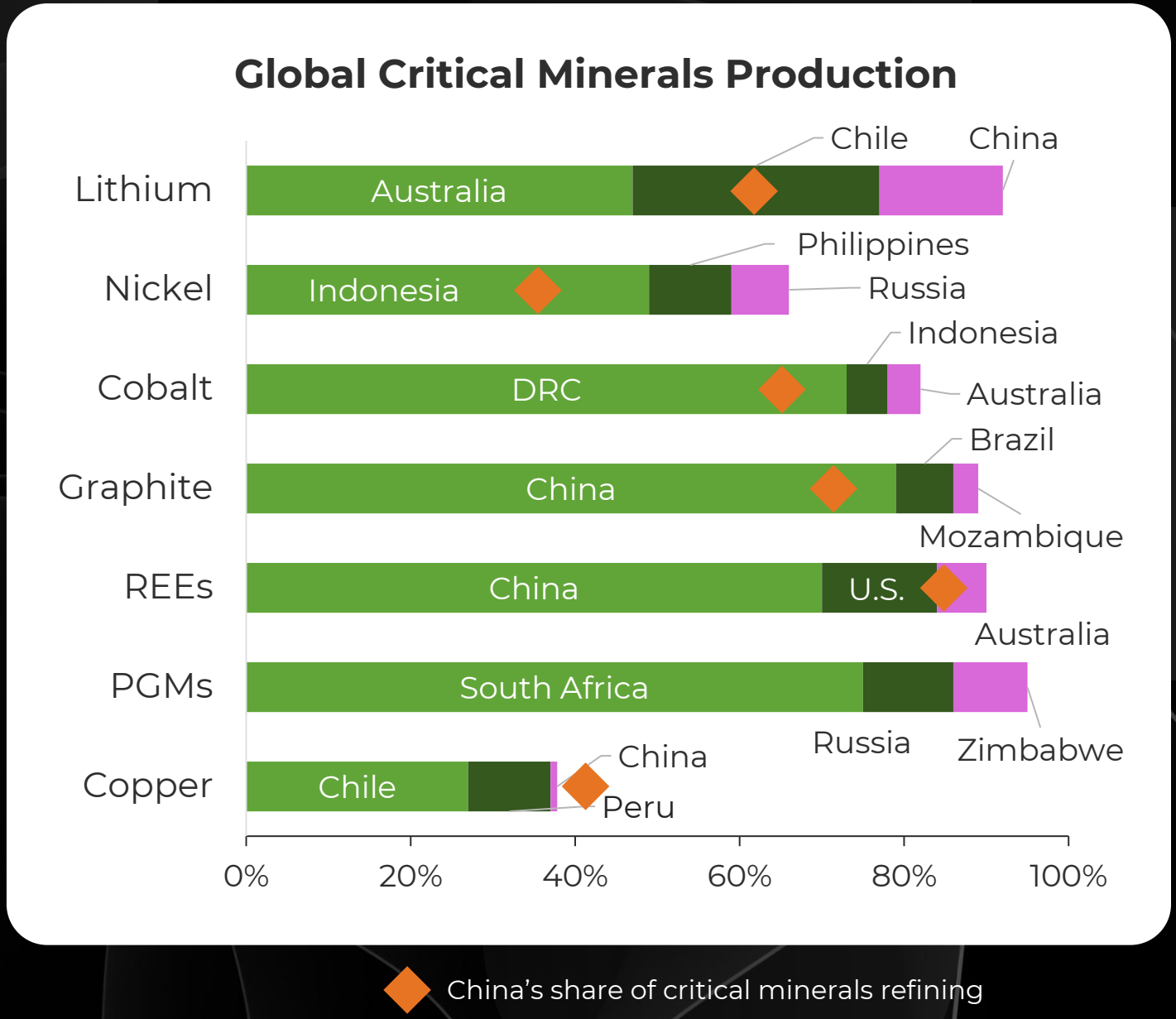
PRECIOUS METALS AND COATINGS ARE 20% TO 40% OF STACK COSTS



Source: IRENA and Lux Research

A MATERIALS BOTTLENECK

- Production is heavily concentrated.
- China hosts >60% of refining capacity in most value chains.
- Several Western nations with decarbonization plans lack reserves and production capacity.



Source: IEA, 2023 (adapted by Lux Research)

AGENDA

01 Green hydrogen

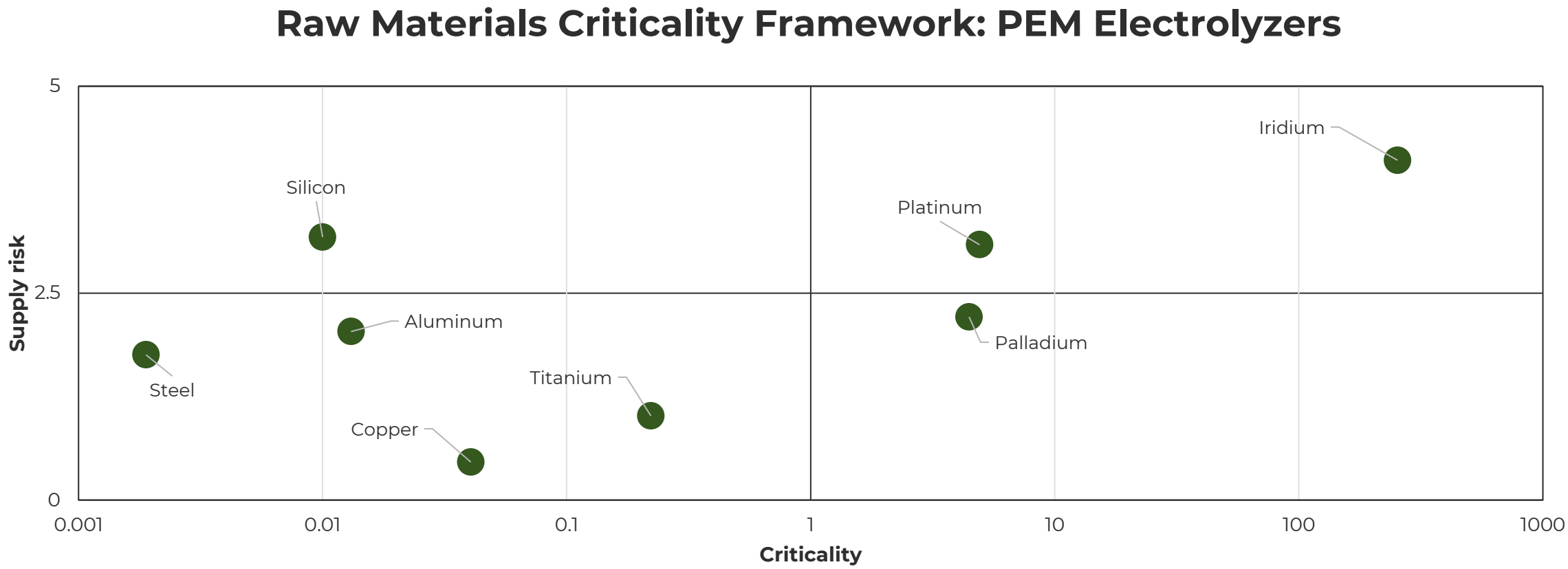
02 **Lux's Raw Materials Criticality Framework**

03 Innovation strategies

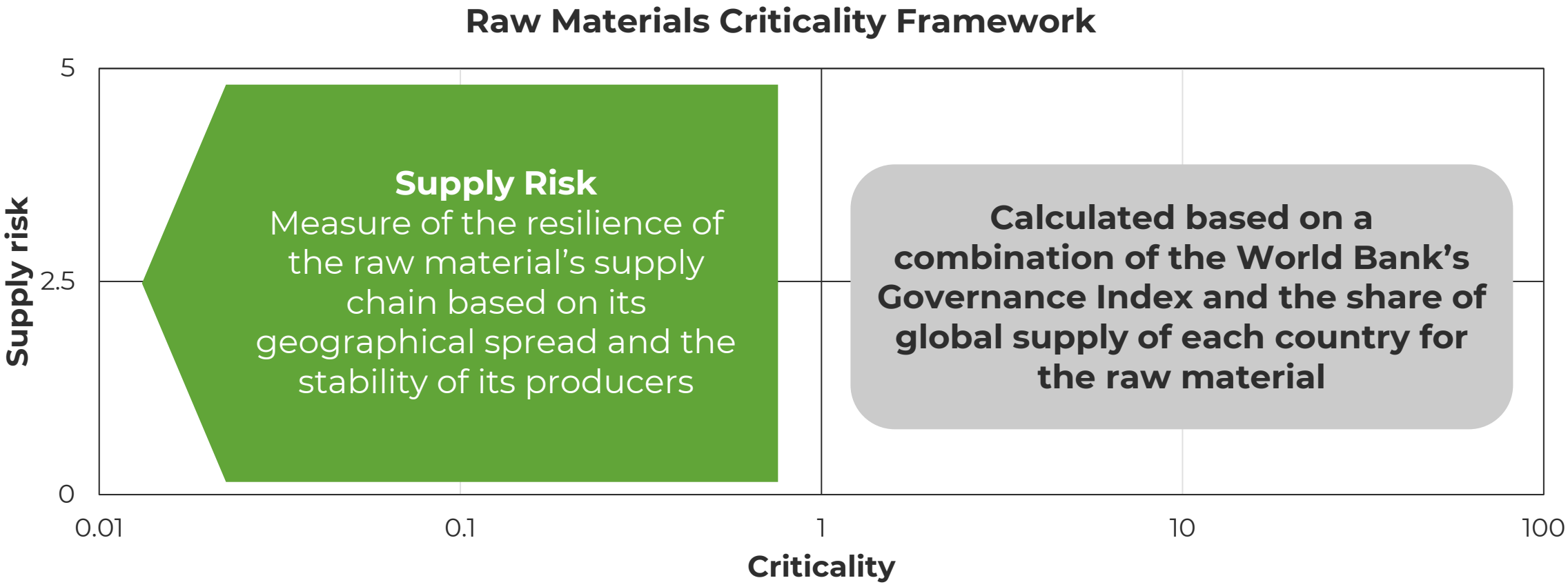
04 Key takeaways

Understand material criticality and supply risk to shape your innovation investments

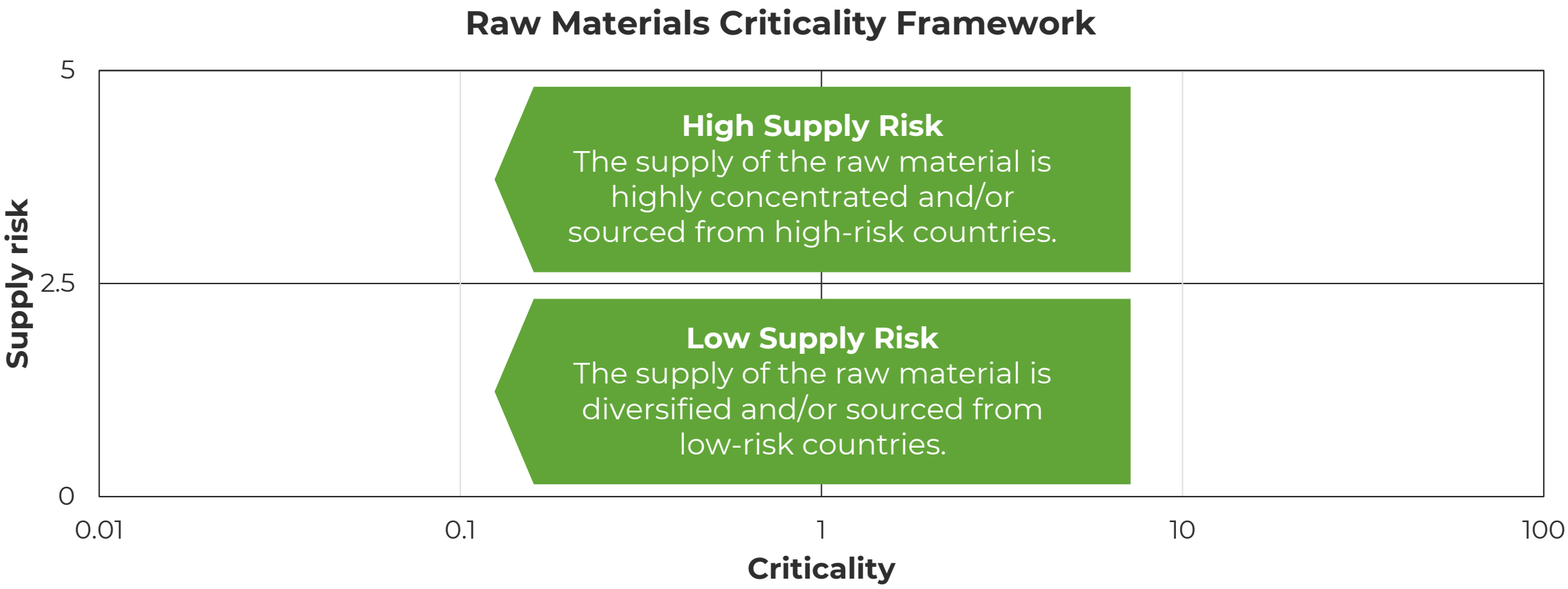
EXAMPLE: PEM ELECTROLYZER



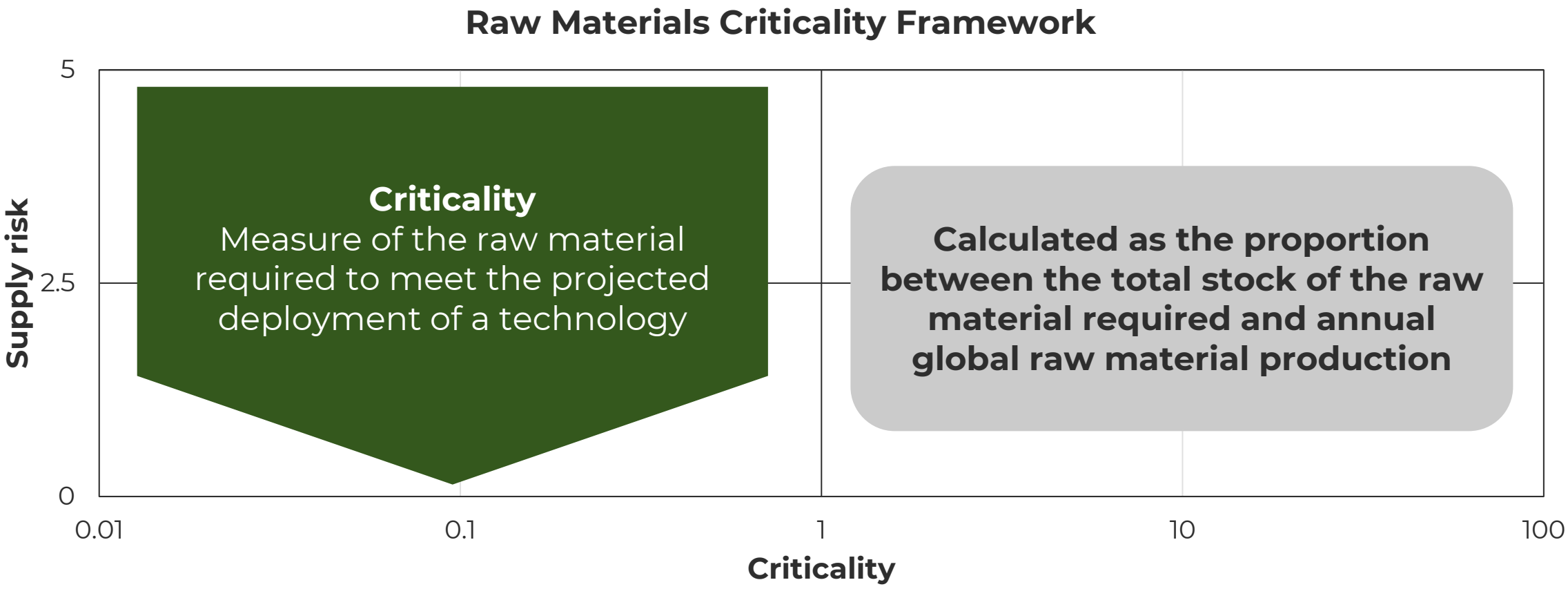
RAW MATERIALS CRITICALITY FRAMEWORK



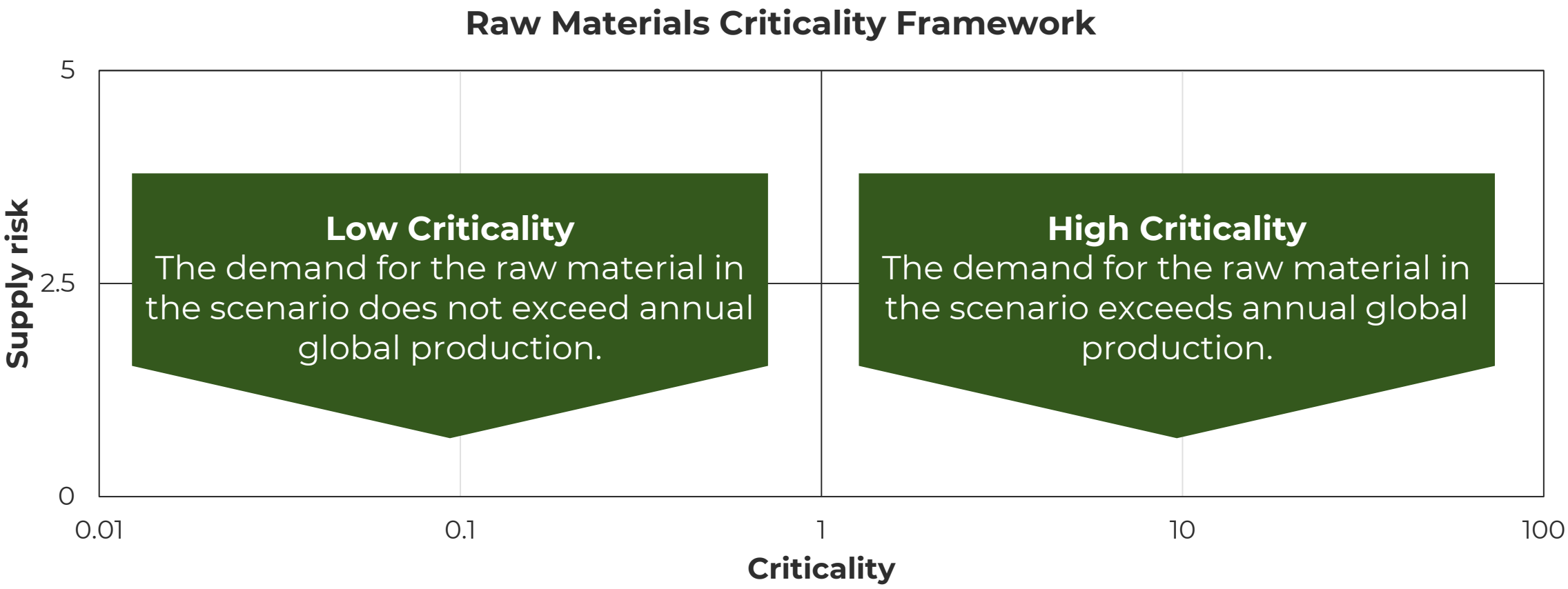
WHAT DOES THE FRAMEWORK TELL US?



RAW MATERIALS CRITICALITY FRAMEWORK



WHAT DOES THE FRAMEWORK TELL US?



So, now what?

AGENDA

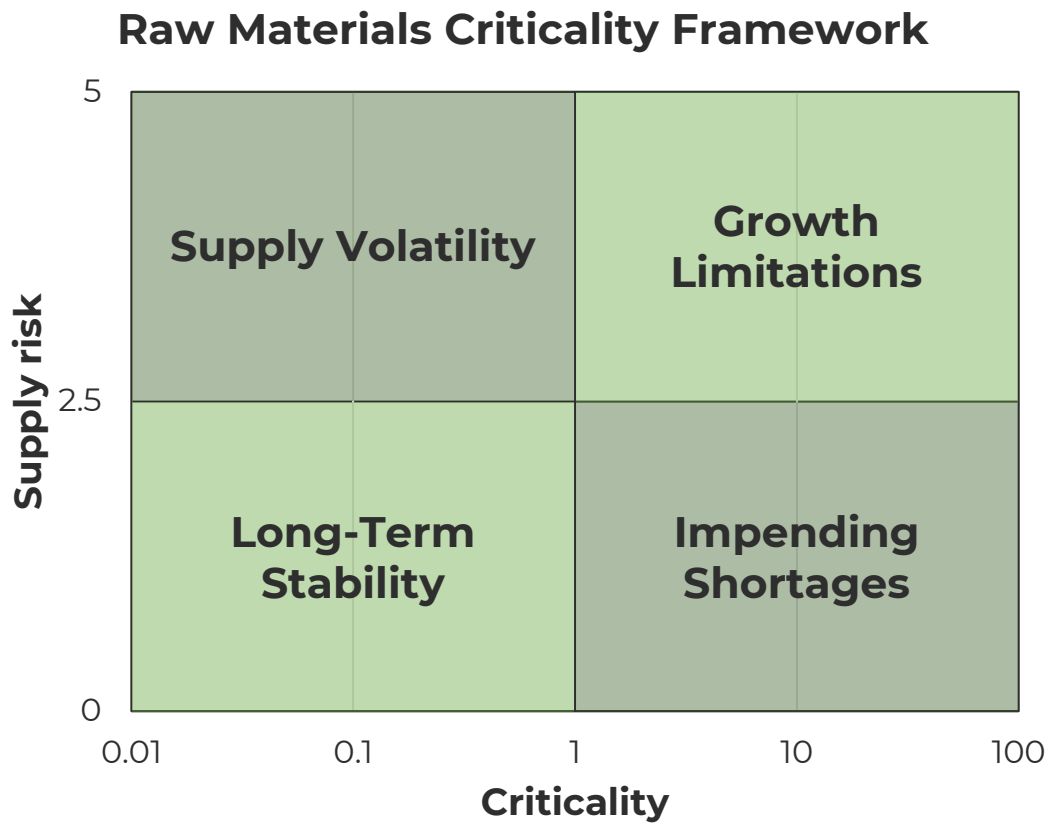
01 Green hydrogen

02 Lux's Raw Materials Criticality Framework

03 **Innovation strategies**

04 Key takeaways

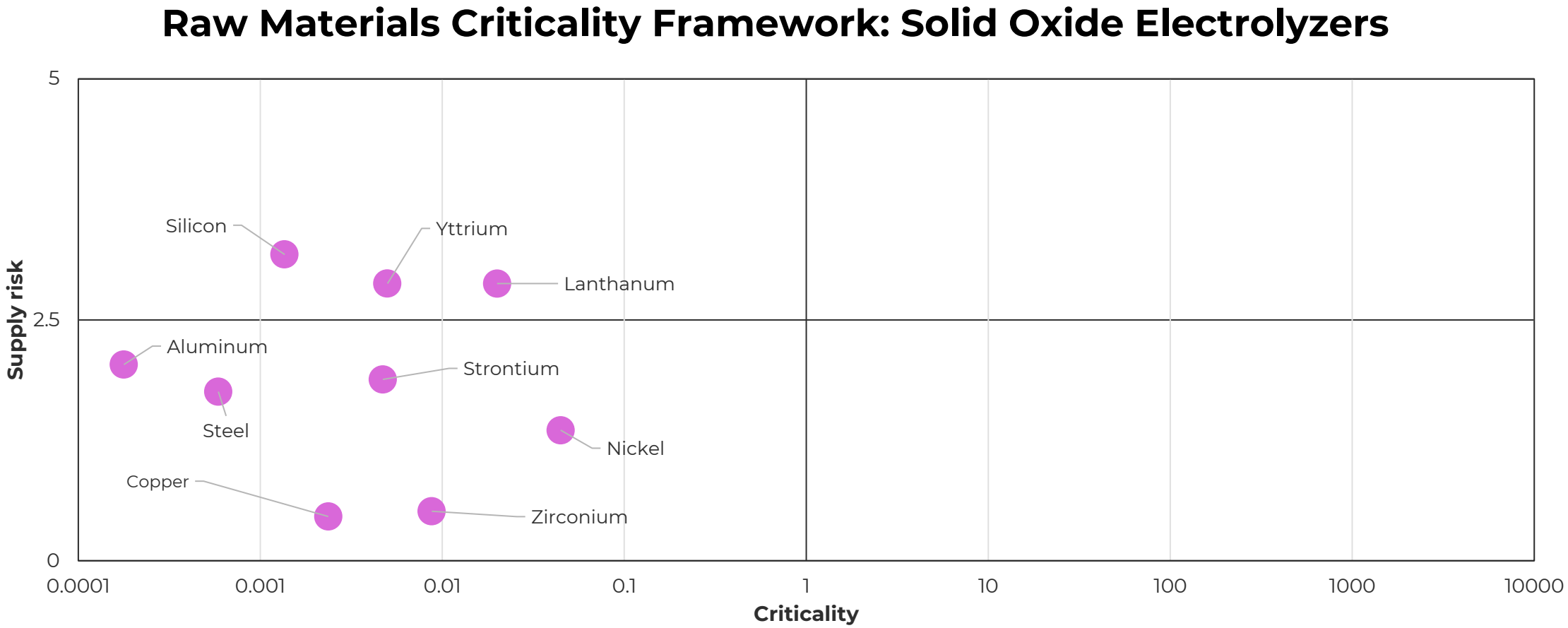
STEP 1: ASSESS YOUR RAW MATERIALS RISKS



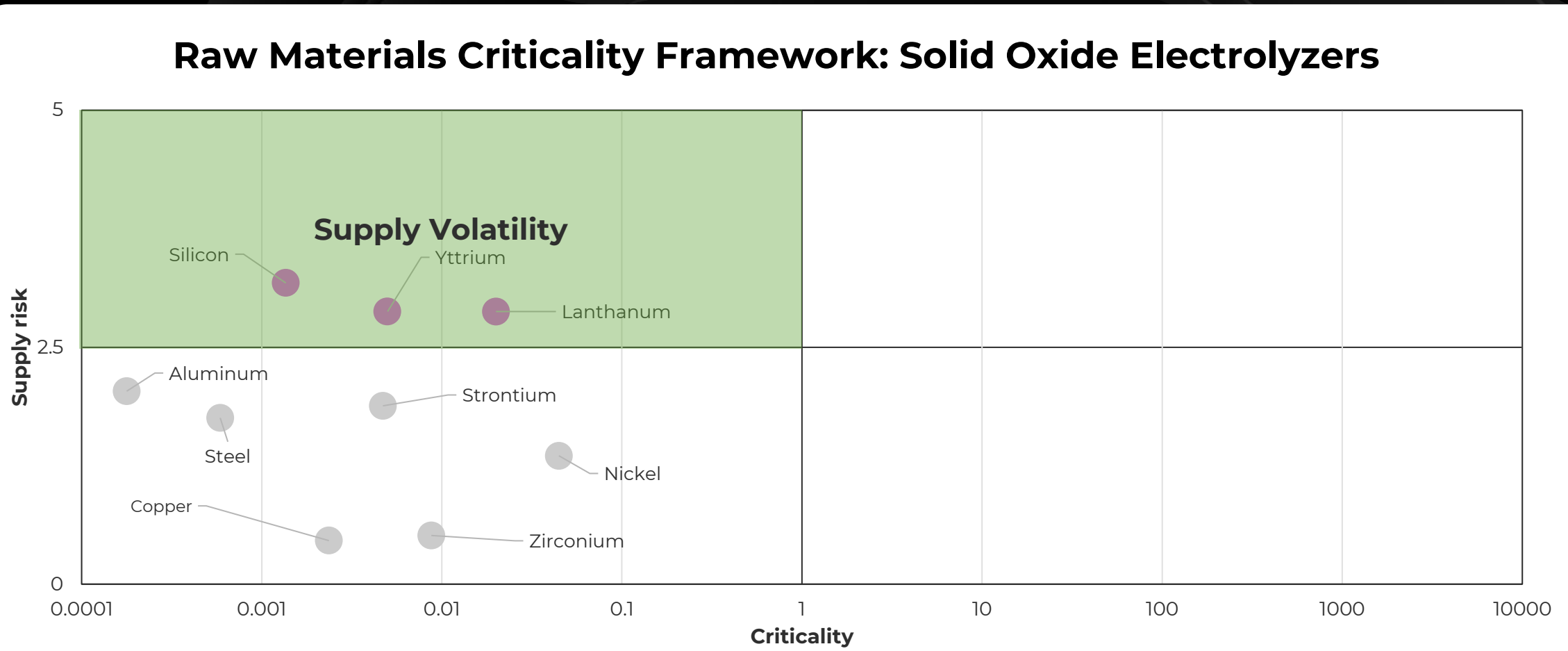
STEP 2: SELECT YOUR INNOVATION STRATEGIES

- Novel Sources
- Materials Optimization
- Alternative Materials
- Recycling & Circularity

SUPPLY VOLATILITY



SUPPLY VOLATILITY: RARE EARTHS



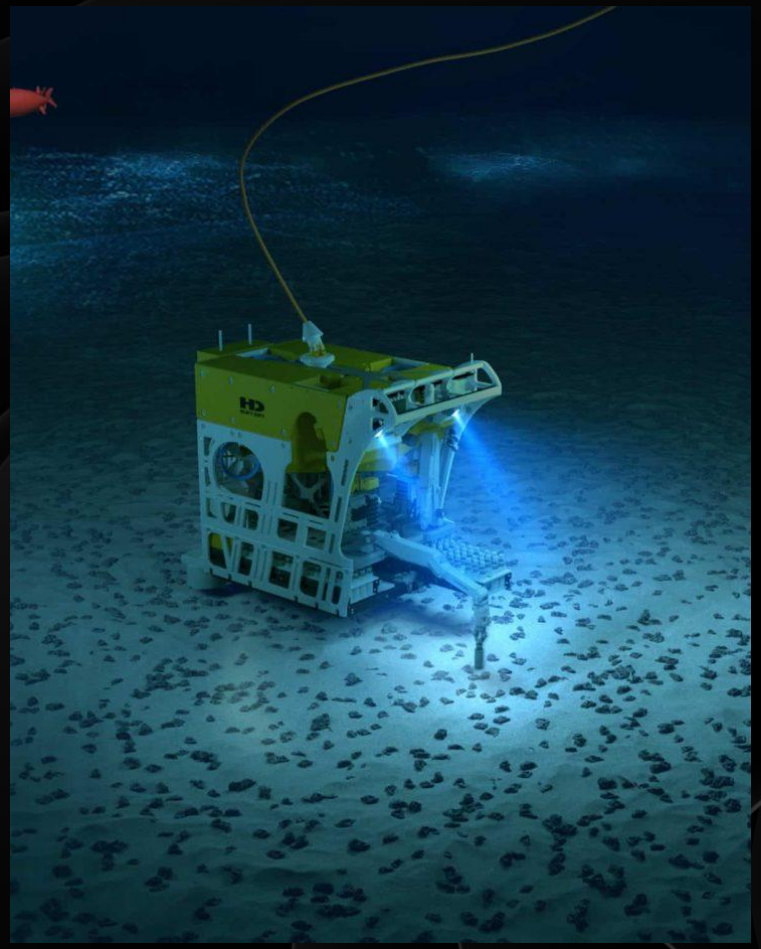
NOVEL SOURCES

Support innovations that supply critical materials from waste streams and unexpected places

Image source: Tailings Dam

COAL ASH

DEEP-SEA MINING



WASTEWATERS

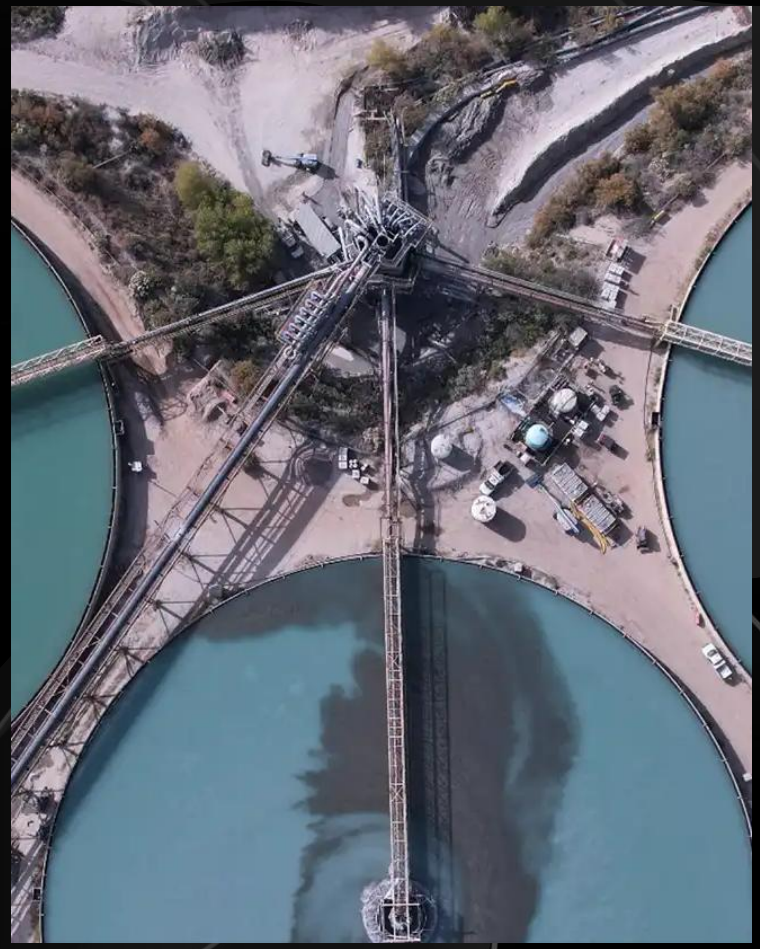
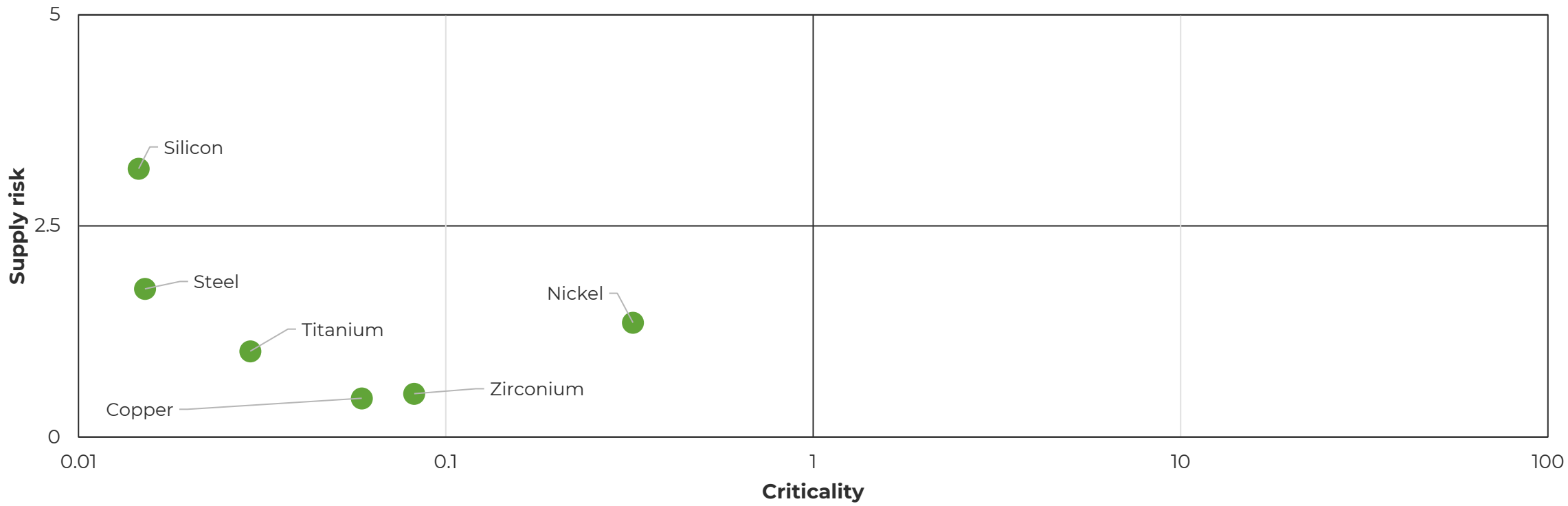
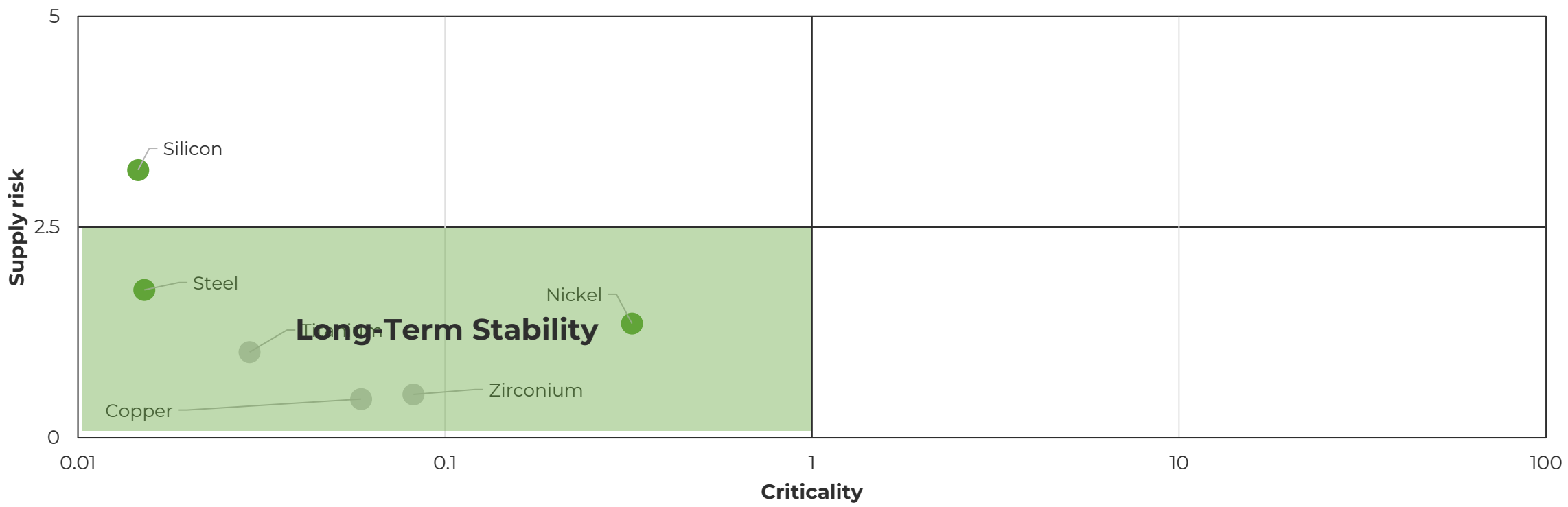


Image sources, left to right: Sierra Club, Loke Marine Minerals, RyO Inginieria

STABILITY



STABILITY: NICKEL



MATERIALS OPTIMIZATION

Allocate R&D resources to projects that can do more with less

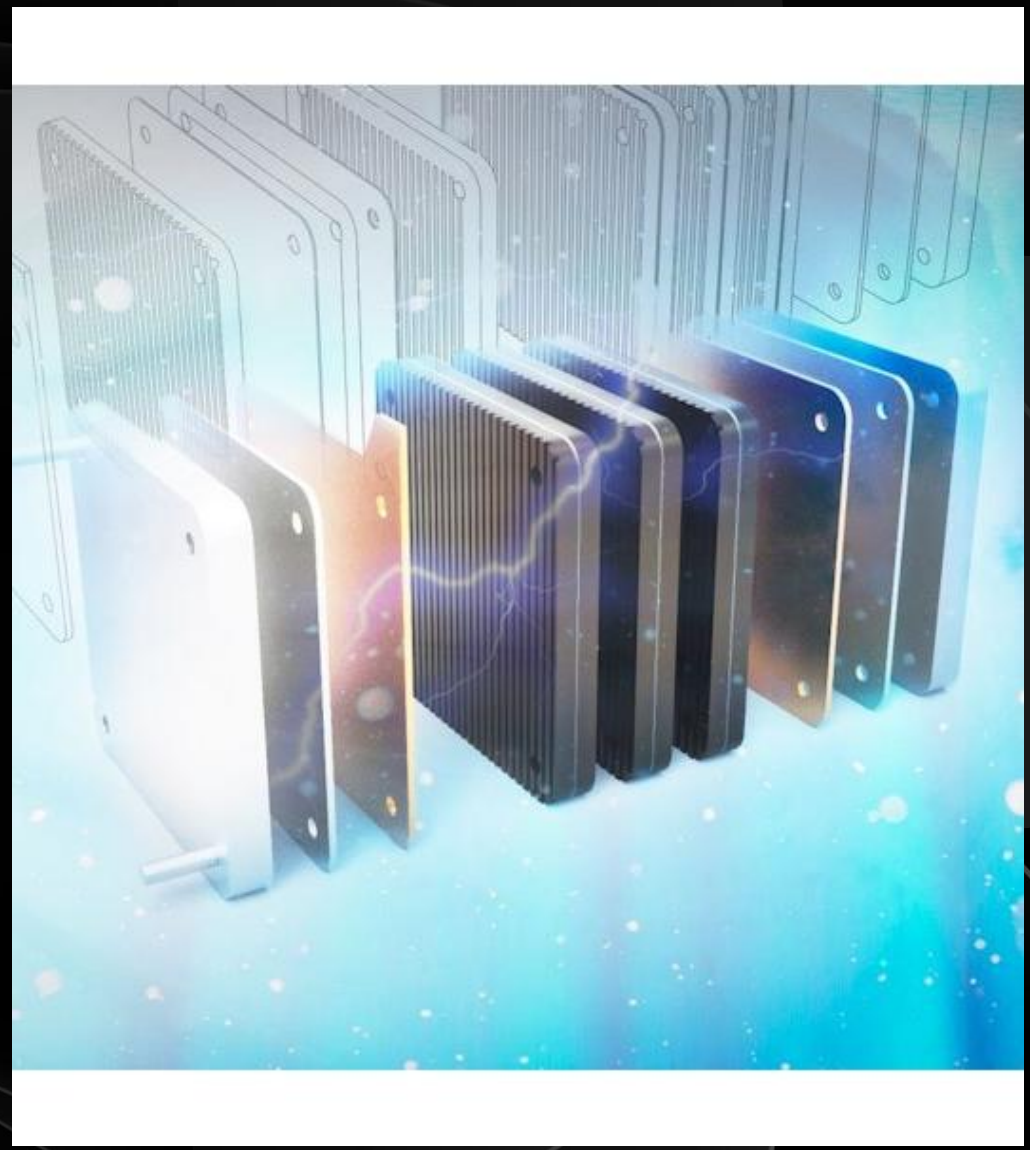
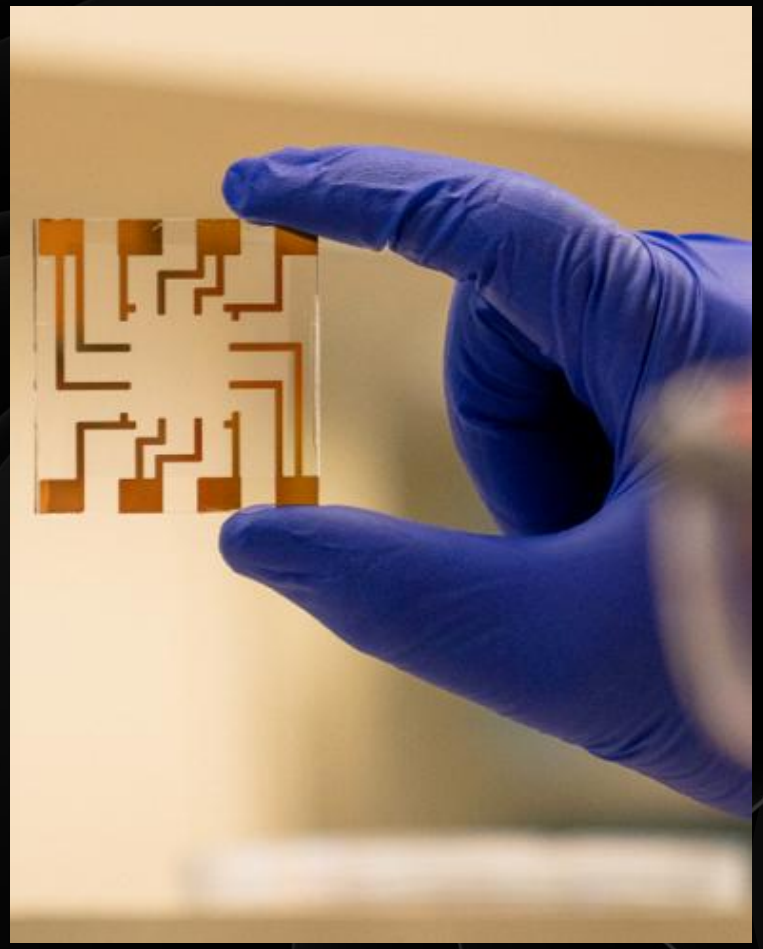


Image source: IDTechEX

ADDITIVE MANUFACTURING

LOWER LOADINGS



AI PROCESS CONTROL

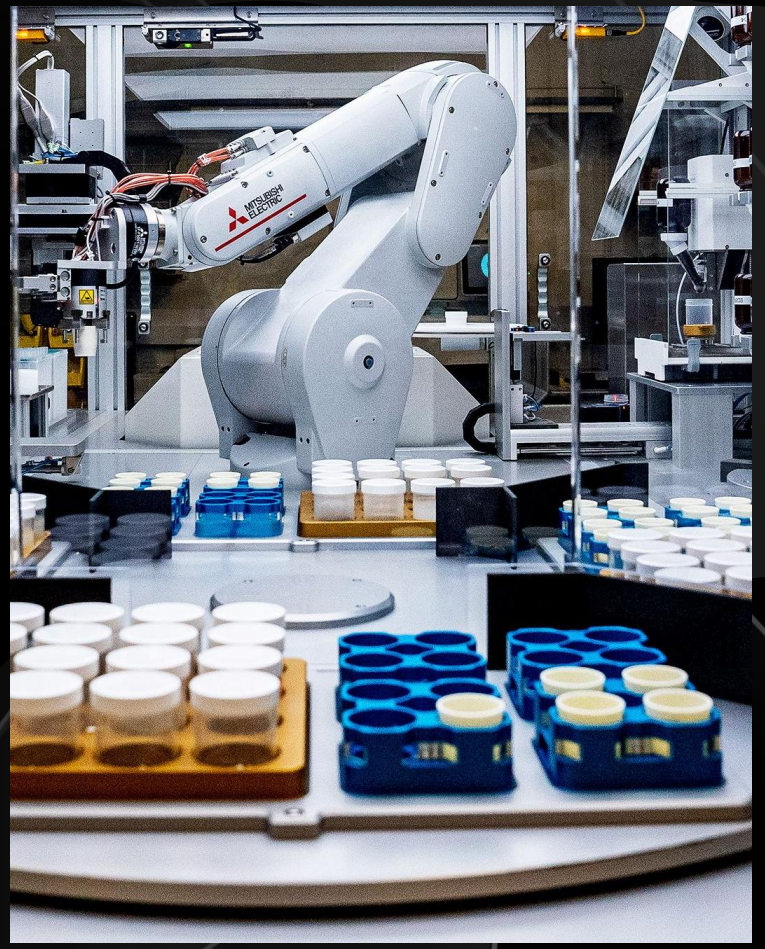
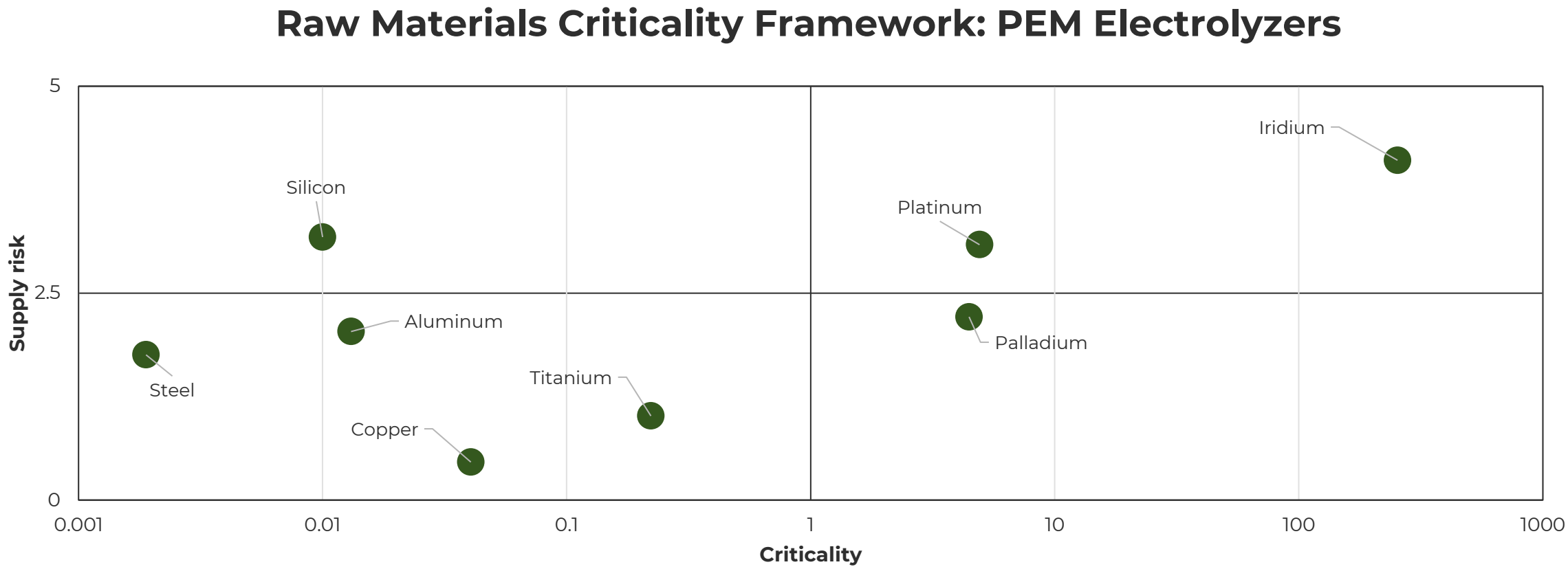
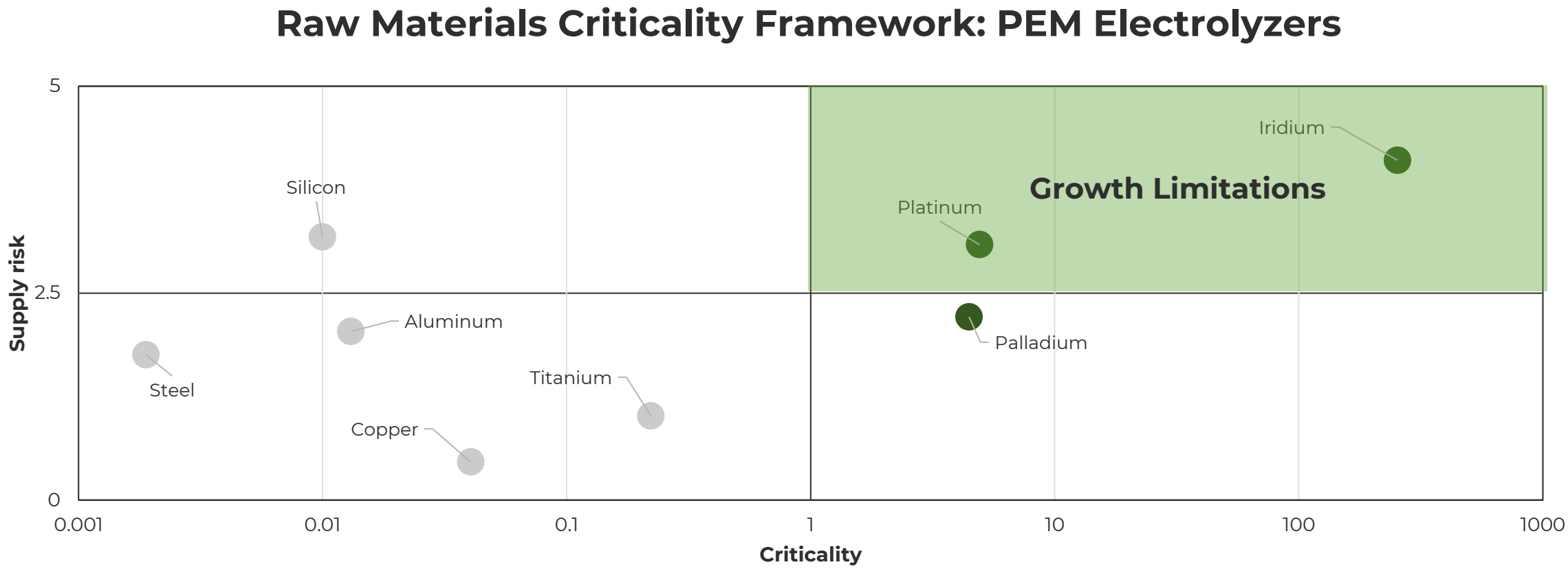


Image sources, left to right: 3D printed catalyst, Mattiq, Mitsubishi Electric Automation

GROWTH LIMITING



GROWTH LIMITING: IRIDIUM



ALTERNATIVE MATERIALS

Identify innovations that that can functionally replace a material input

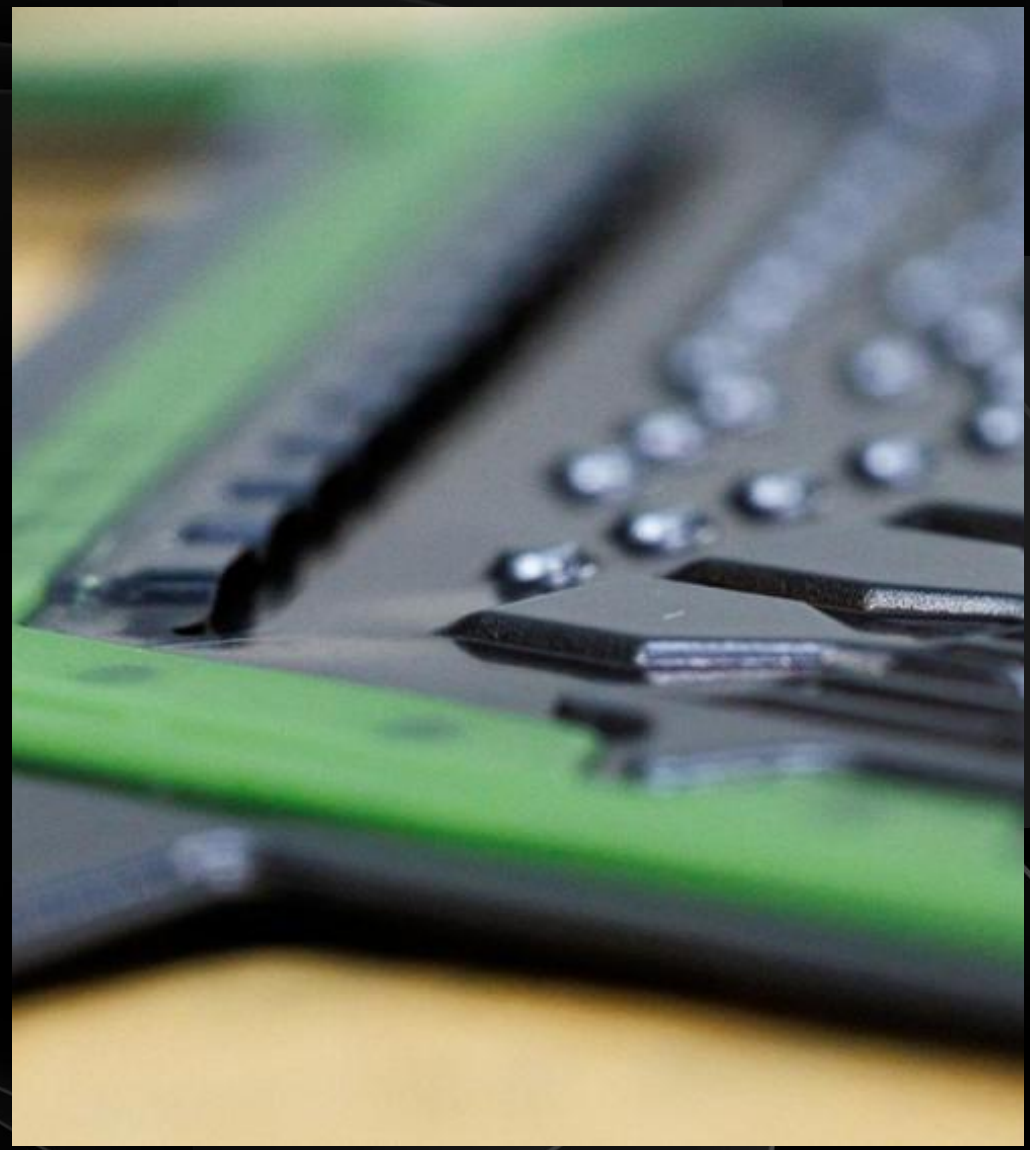


Image source: Schaeffler Group

ALTERNATIVE CHEMISTRY

COMPOSITES

AVOIDING LIMITATIONS

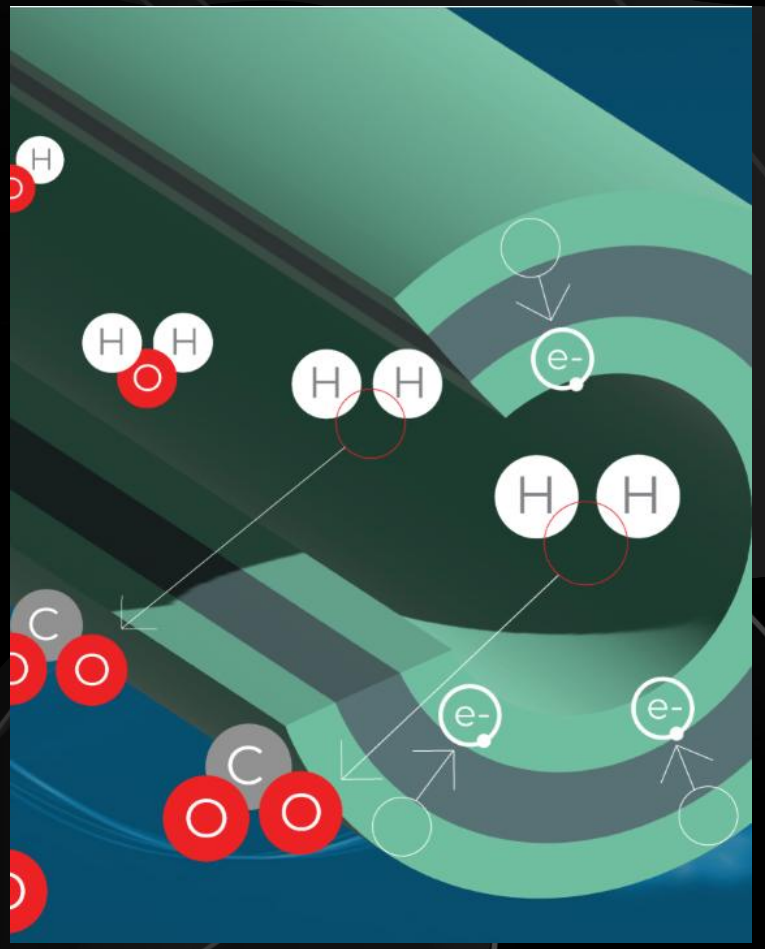
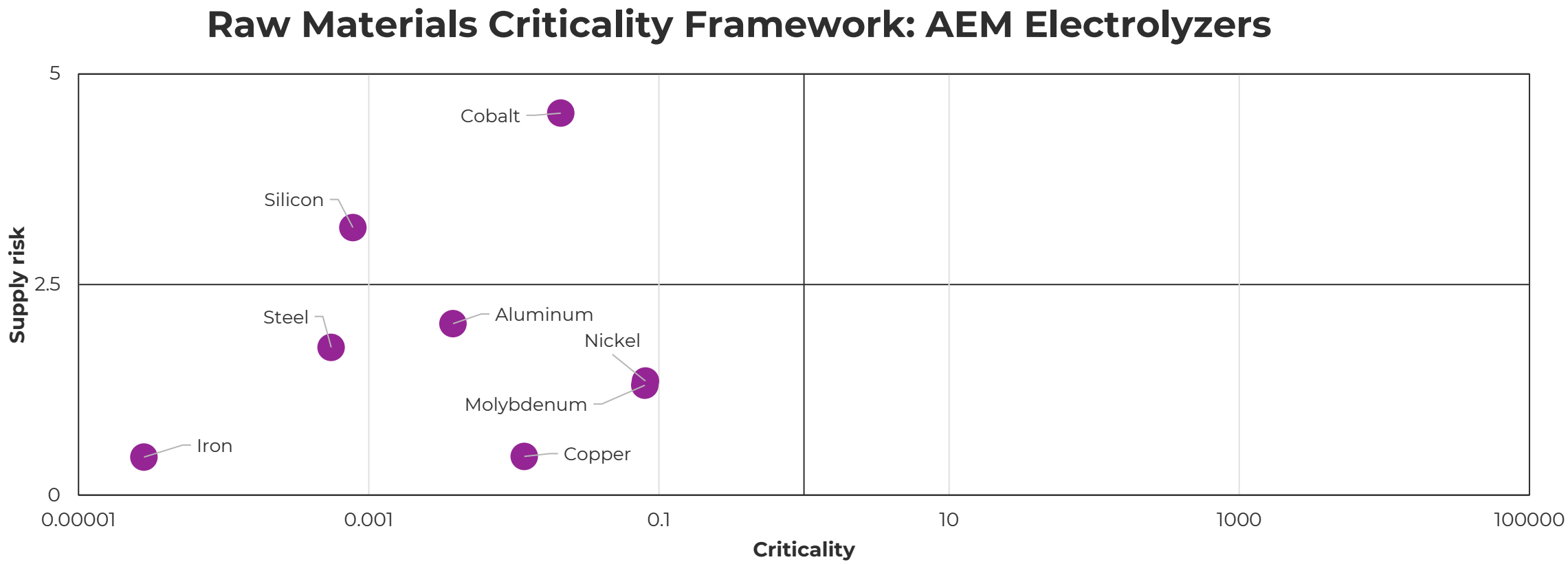
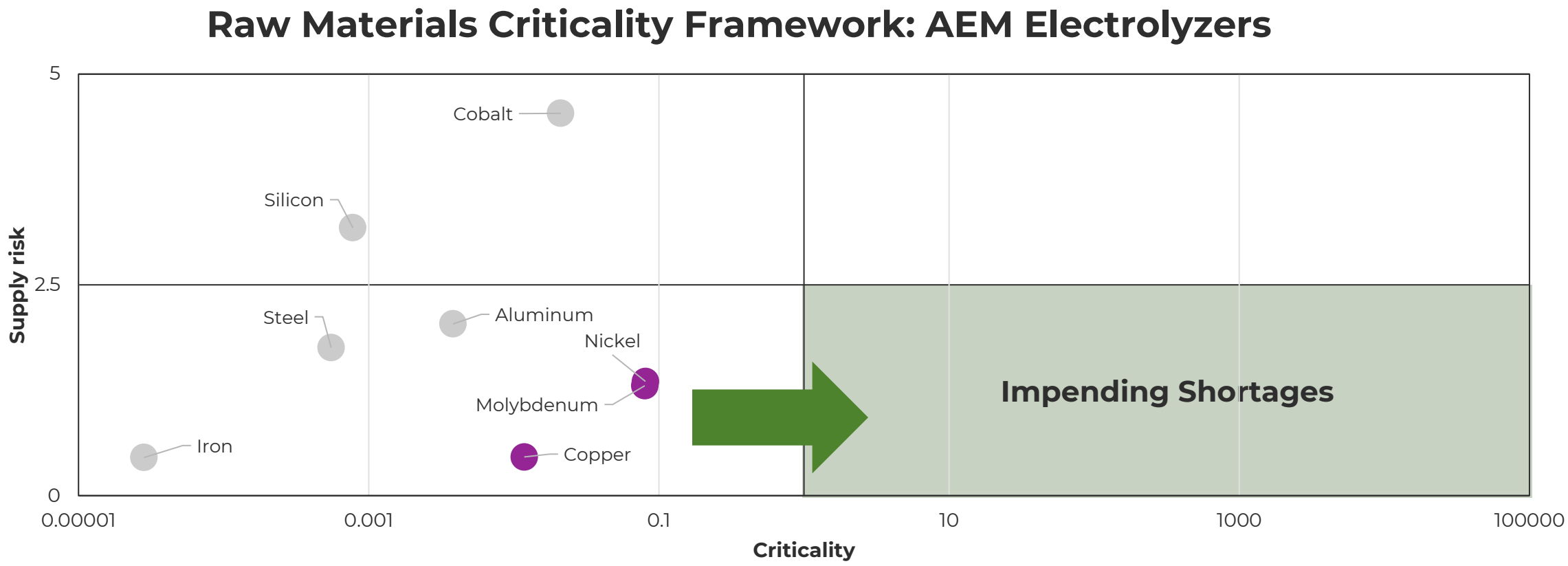


Image sources: Ionomr, Siltrax, Clean Technica

IMPENDING SHORTAGES



IMPENDING SHORTAGE: COPPER



RECYCLING & CIRCULARITY

Maximize recovery of resources from products within your reach

Image source: Li-Cycle Battery Recycling

RECYCLING SERVICES

DESIGNING FOR CIRCULARITY

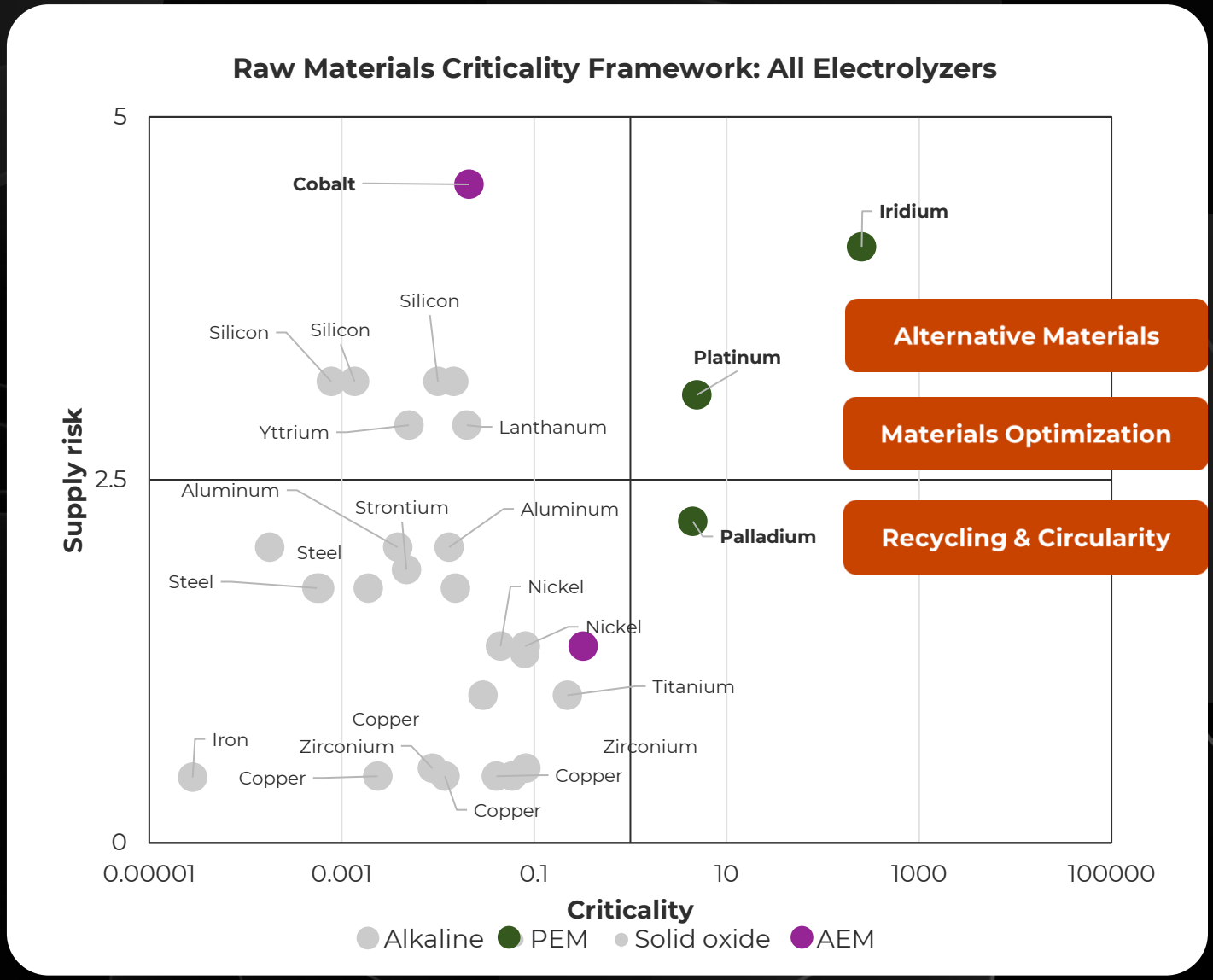
IMPROVING COLLECTION

Image sources, left to right: Bosch,, Ensinger, New Way

Use the framework to select the right innovation strategies

IMPLICATIONS

- Materials high in supply risk and criticality can limit growth
- High Supply Risk but moderate to low Criticality
- Commodity metals present a low risk

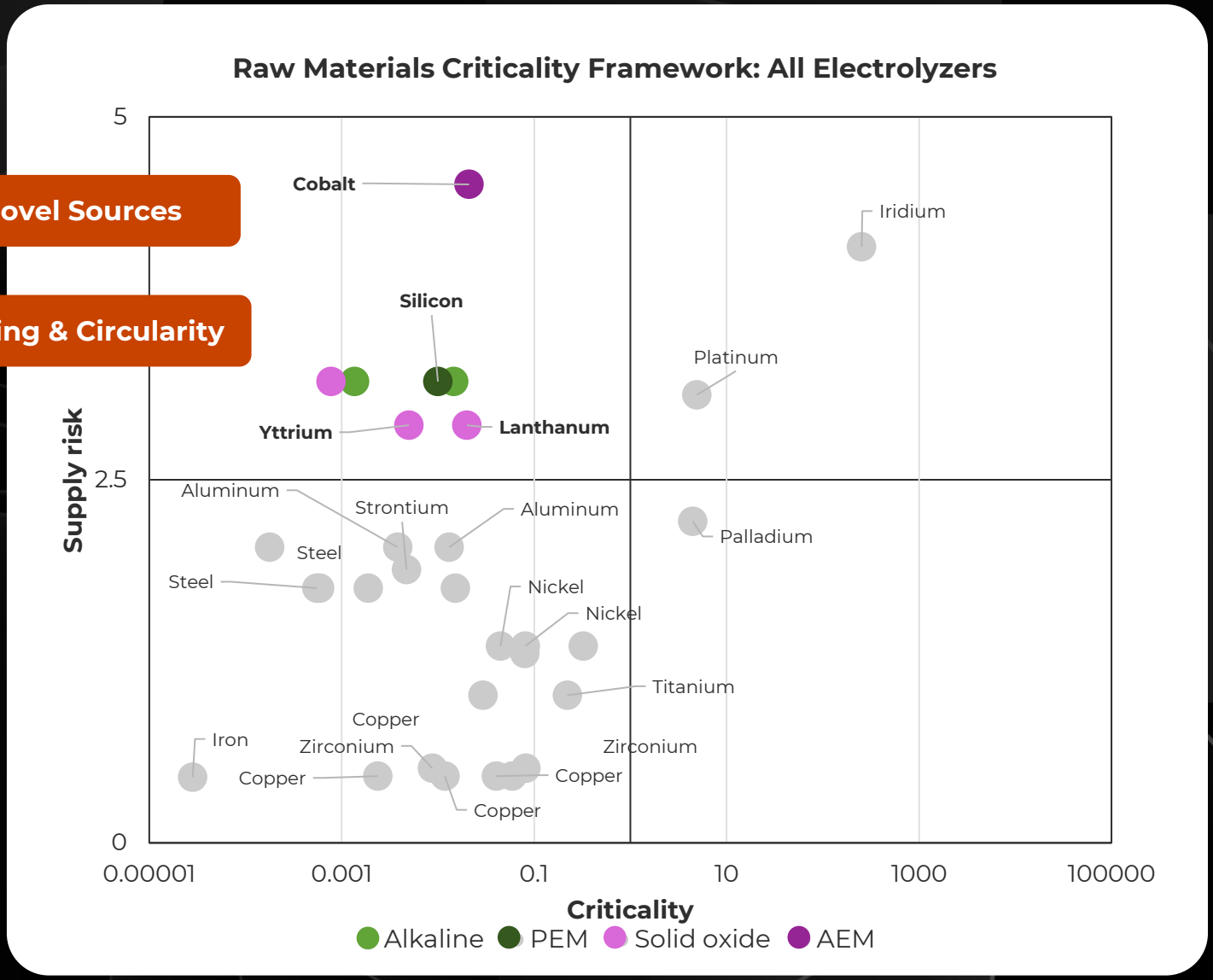


IMPLICATIONS

- Materials high in Supply Risk and Criticality can limit growth
- High supply risk but moderate to low criticality
- Commodity metals present a low risk

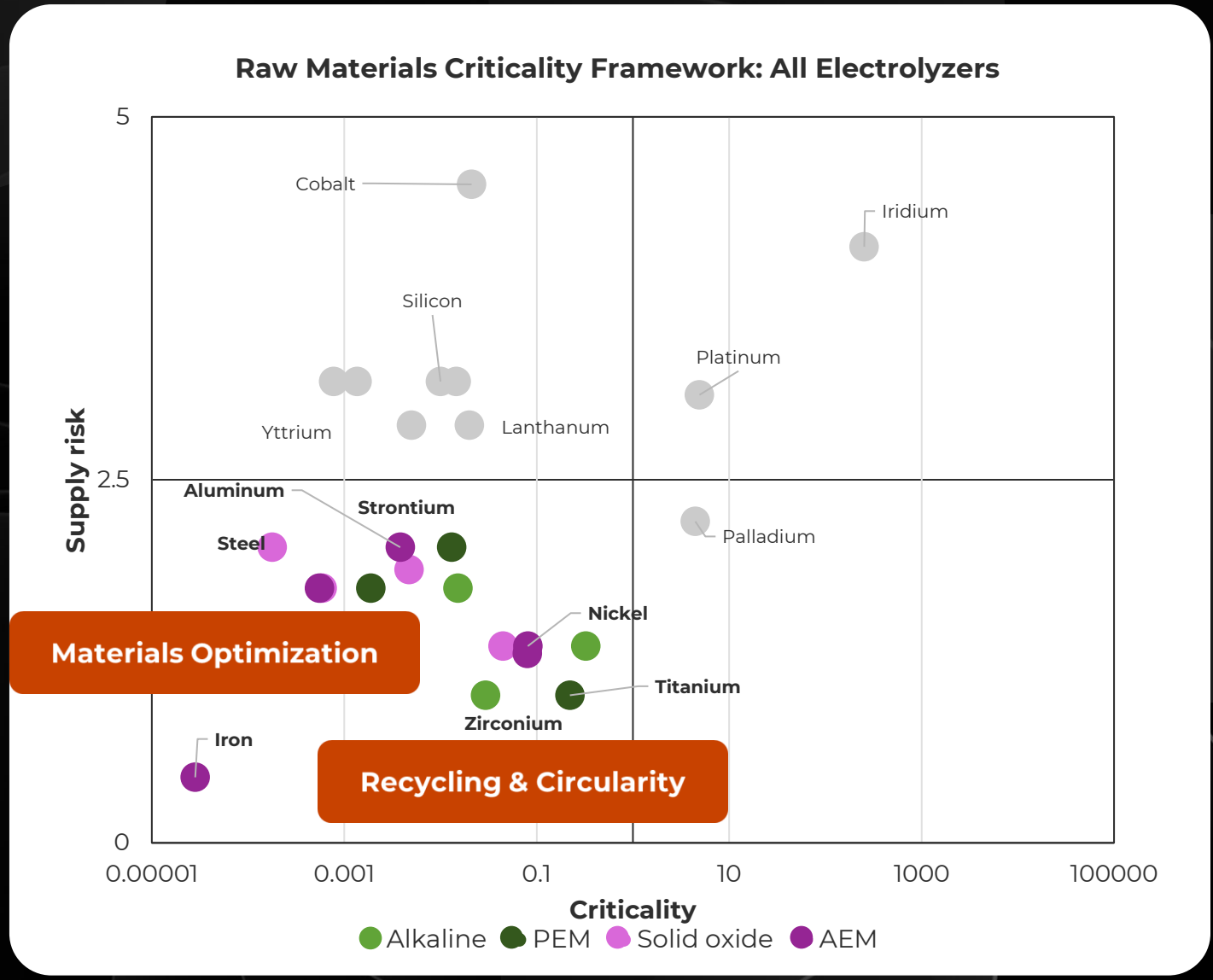
Novel Sources

Recycling & Circularity



IMPLICATIONS

- Materials high in Supply Risk and Criticality can limit growth
- High Supply Risk but moderate to low Criticality
- Commodity metals present a low risk



PEAK PHOSPHATE SOLUTIONS

We've found a way to stave off a crisis

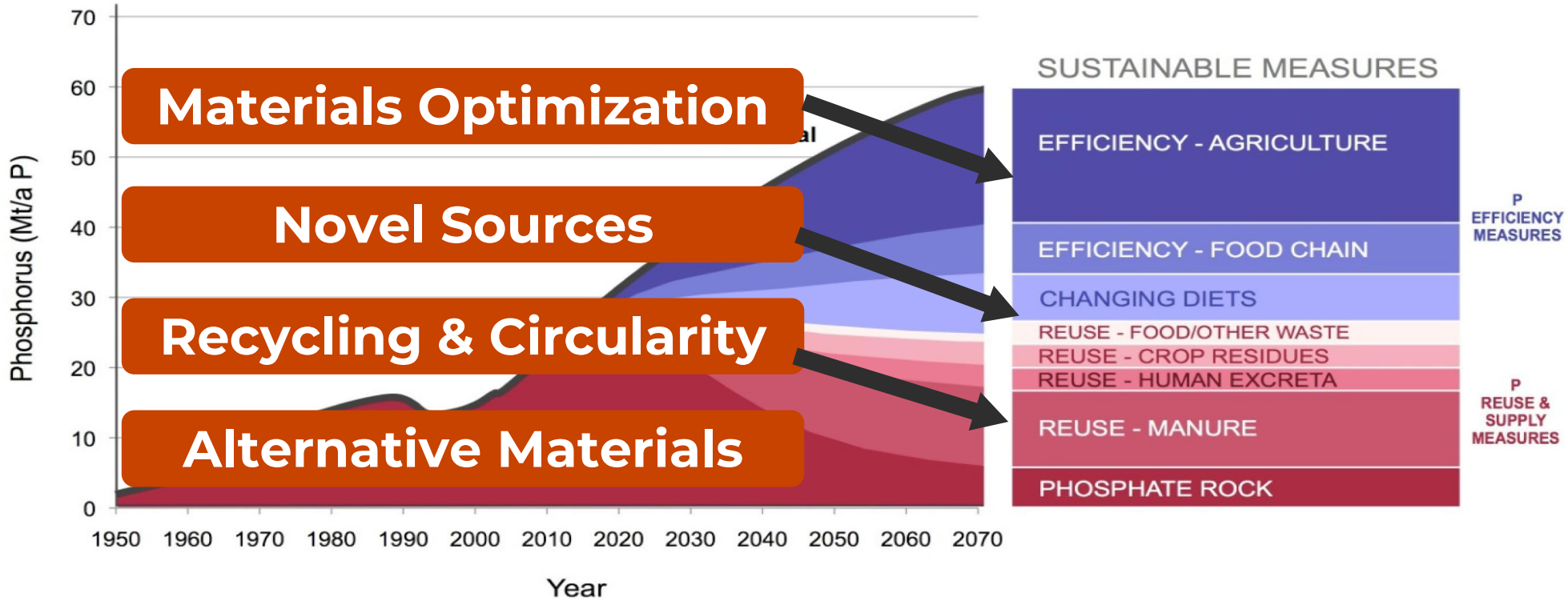


Image source: Institute for Sustainable Future

AGENDA

01 Critical minerals driving the Energy Transition

02 Lux's Raw Materials Criticality Framework: Green Hydrogen

03 Innovation strategies

04 **Key takeaways**

KEY TAKEAWAYS

1

Access to materials is decisive for technology viability.

Overreliance on precious metals can limit electrolyzer scalability unless electrochemists and specialty materials developers replace materials with a high criticality score.

2

Diversify so that low-criticality materials today don't create tomorrow's bottleneck.

As EVs, grid storage, renewables, and other clean tech infrastructure scale, cross-sector demand for commodity materials will create supply and price volatility.

3

Energy companies can leapfrog materials limitations with Hydrogen 2.0 tech.

Invest early in low-TRL but high-efficiency technologies emerging today: Hydrogen 2.0 technologies without supply constraints could become the winners in the long run.

THANK YOU

READ

http://www.luxresearchinc.com/blog/

LISTEN

Innovation Matters Podcast - Spotify

VISIT

www.luxresearchinc.com

EMAIL

questions@luxresearchinc.com

FOLLOW

@LuxResearch

CONNECT

LuxResearch

ABOUT LUX

Lux Research fuels innovators to not only imagine what's possible in the future but also operationalize innovation success in the near term. We deliver research and advisory services to inspire, illuminate, and ignite innovative thinking that reshapes and grows businesses. Using quality data derived from primary research, fact-based analysis, and opinions that challenge traditional thinking, our experts focus on finding truly disruptive innovations that are also realistic and make good business sense.

The "Lux Take" is trusted by innovation leaders around the world, many of whom seek our advice directly before placing a bet on a startup or partner — our clients rely on Lux insights to make decisions that generate fantastic business outcomes. We pride ourselves on taking a rigorous, scientific approach to avoid the hype and generate unique perspectives and insights that innovation leaders can't live without.

READ
http://www.luxresearchinc.com/blog/

VISIT
www.luxresearchinc.com

FOLLOW
@LuxResearch

CONNECT
LuxResearch

LISTEN
Innovation Matters Podcast - Spotify

EMAIL
questions@luxresearchinc.com