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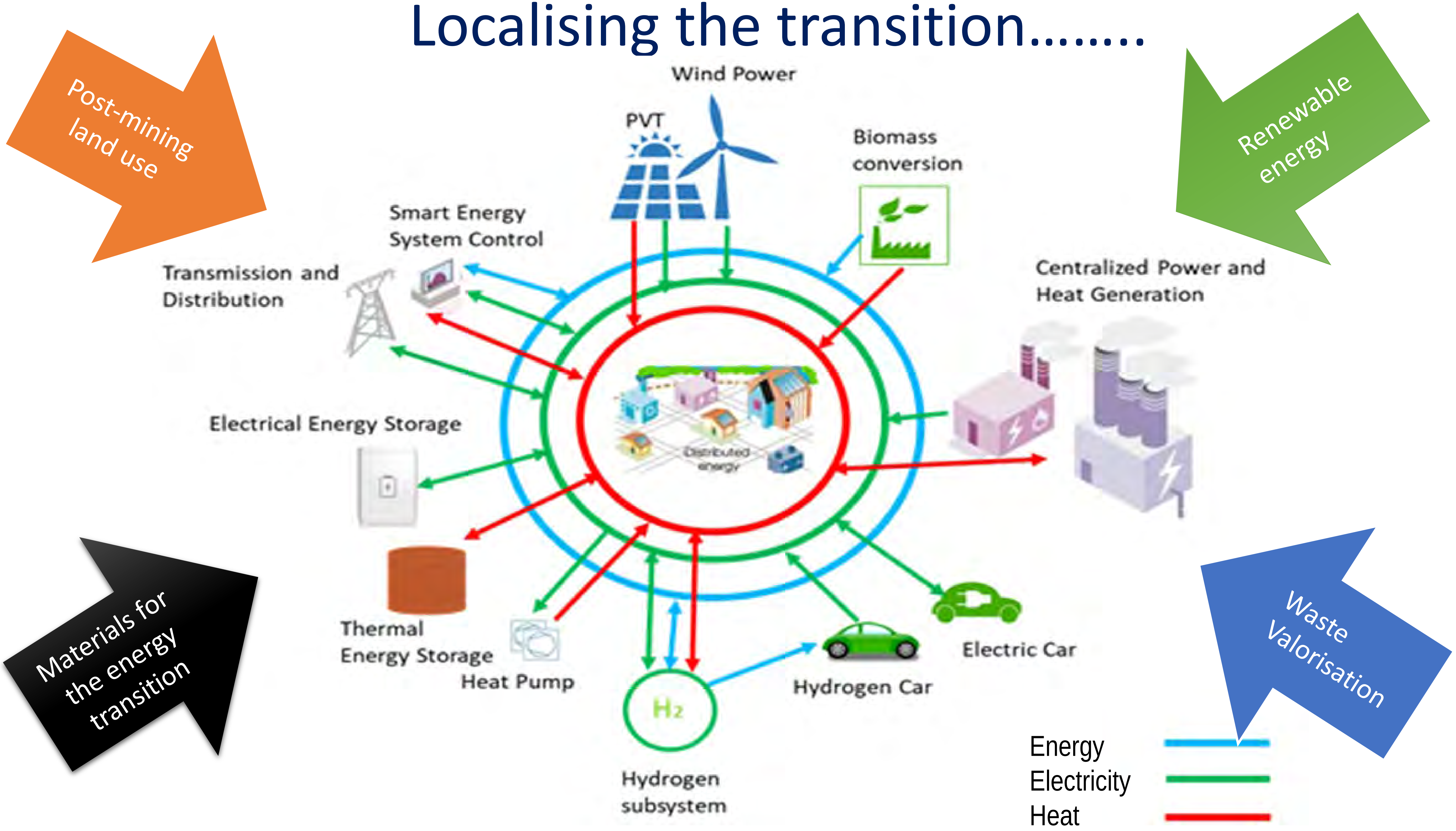
# Can South Africa's mineral wealth be leveraged for the transition?

## Beneficiation through the lens of economic complexity

# Contents

# Localising the transition……..



# A cross-disciplinary research process

- Stage 1: Refining the focus of the research study (DPRU + M2M)
- Stage 2: Identification of products residing in manganese value chain (M2M)
- Stage 3: Map manganese value chain products to trade data (DPRU + M2M)
- Stage 4: Applying the frontier product approach to identify manganese value chain products that are both feasible (distance/density) and desirable (complexity) (DPRU)
- Stage 5: Techno-economic analysis to assess the opportunities and challenges associated with manganese value chain products (DPRU + M2M)

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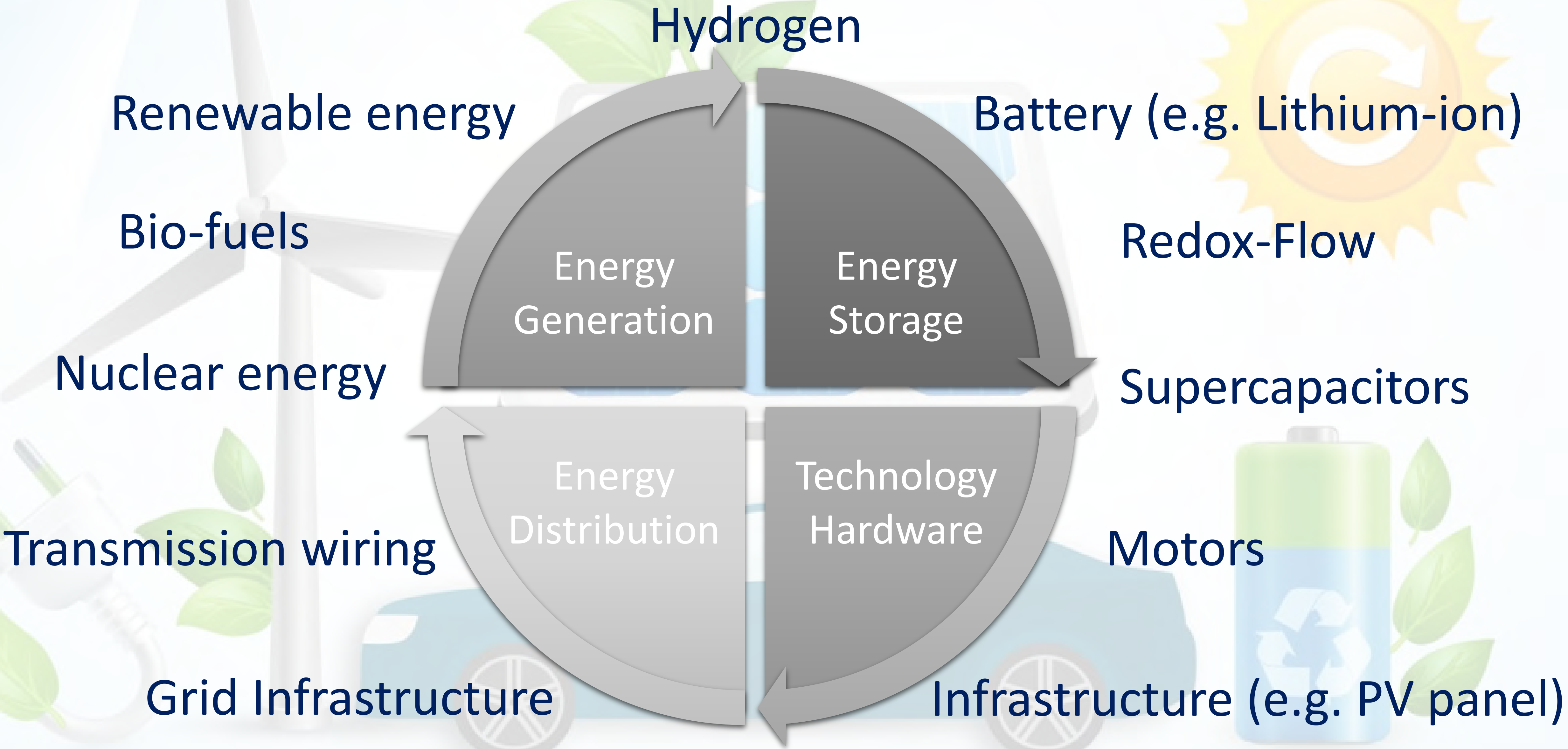
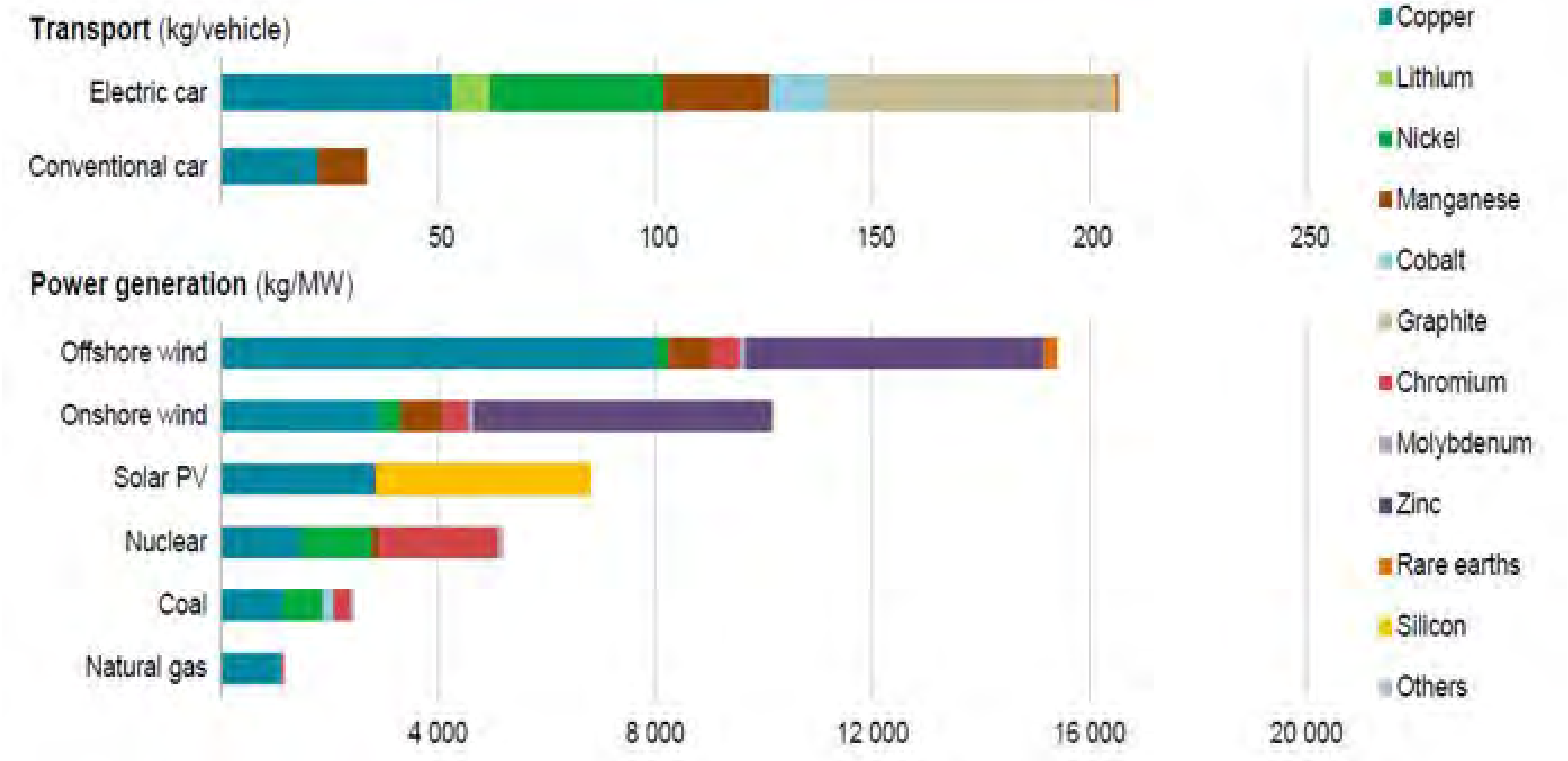
# Background

Shifting to a low-carbon future

# Critical technology for a low-carbon future and green economy

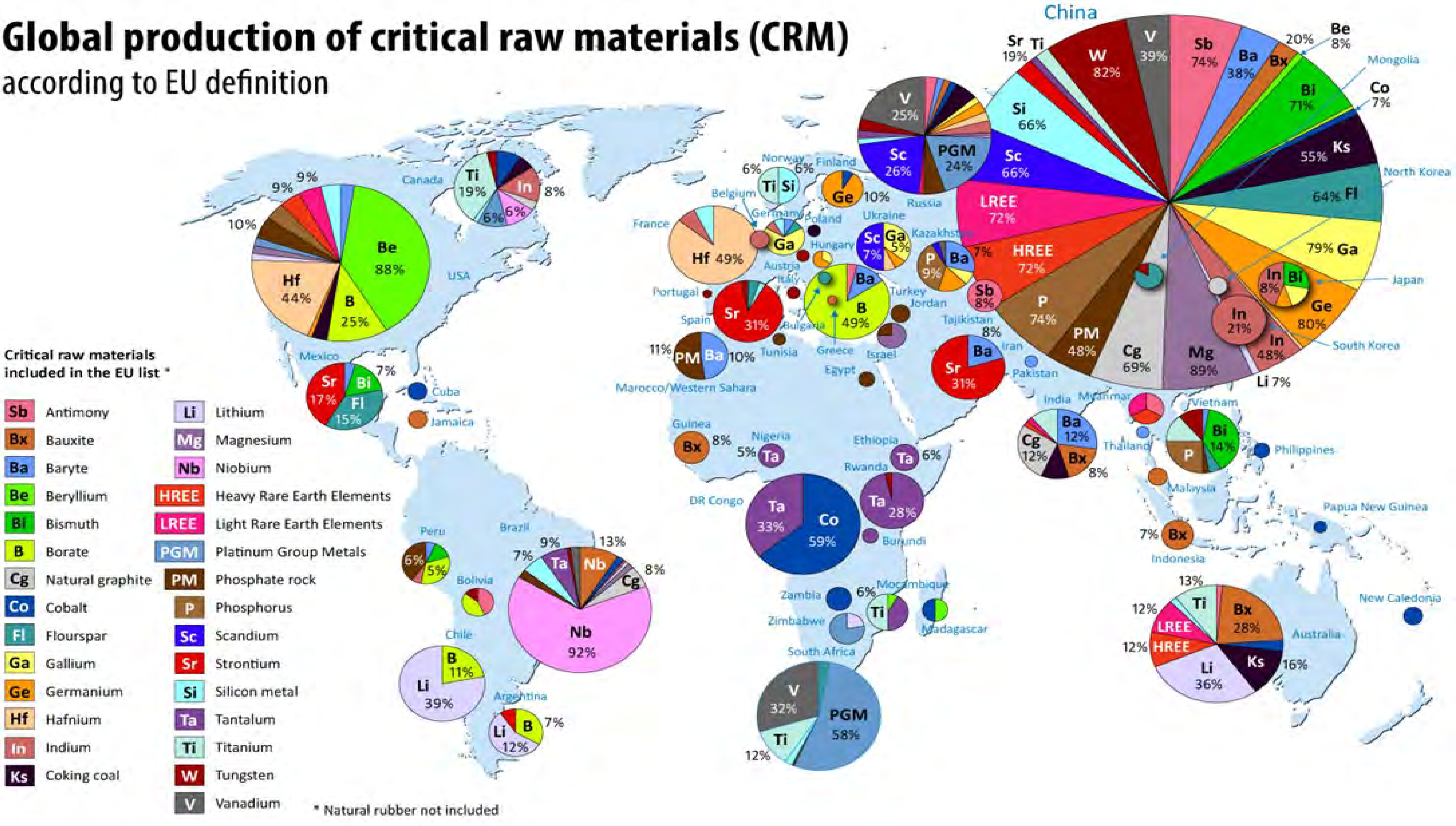


# More materials will be needed for the transition…..



# Global production of critical raw materials (CRM)

according to EU definition



# Current value chains for “critical” materials

**Raw minerals and materials**

Mineral ores
Mineral concentrates

**Intermediate materials**

Battery precursors
Cathode materials
Anode materials
Alloy products
Catalysts

**Finished products**

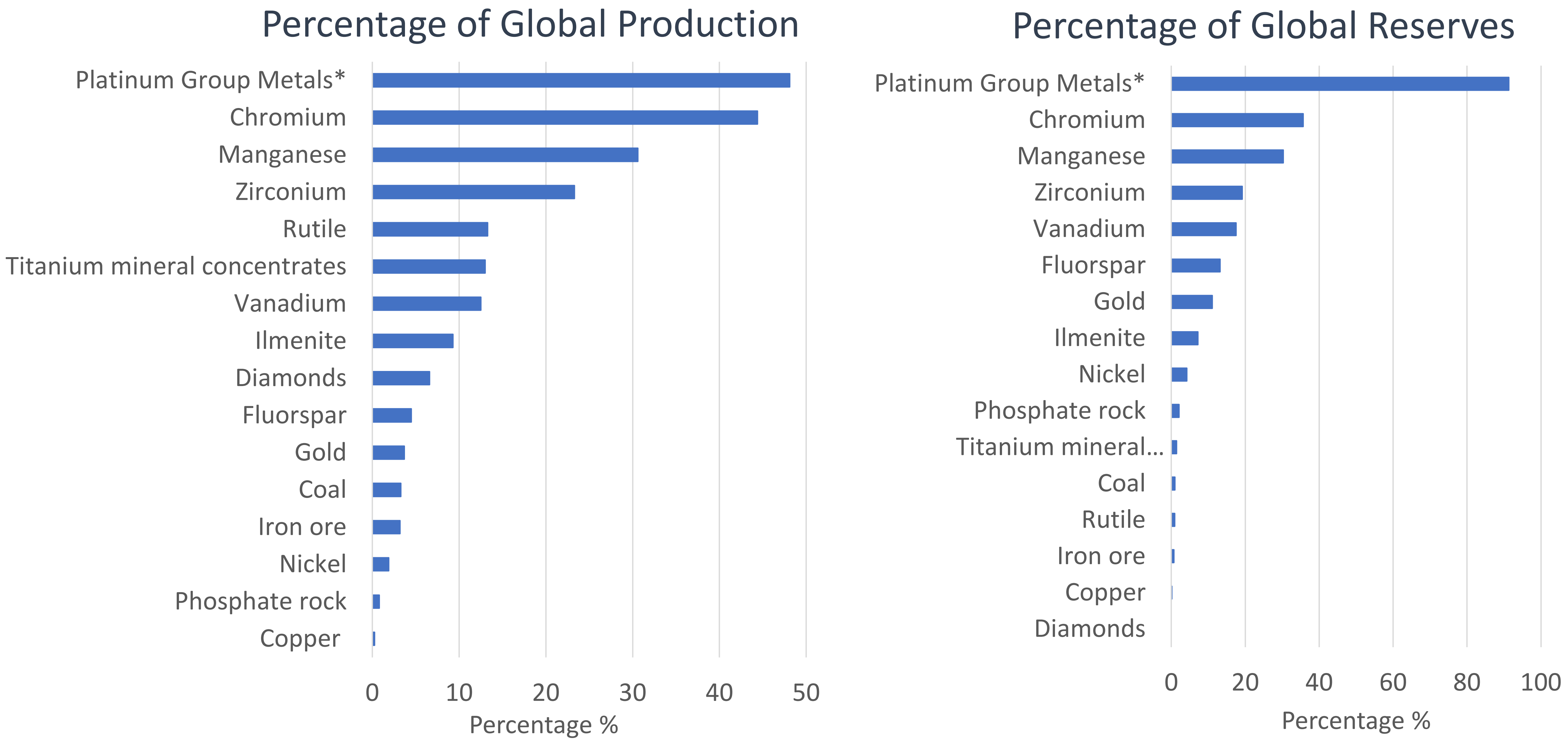
Battery stack
EVs
Fuel Cells
Electrolysers
Solar panel
Wind turbine
Motors
Catalytic converters

Recycling

# South African Mineral Landscape

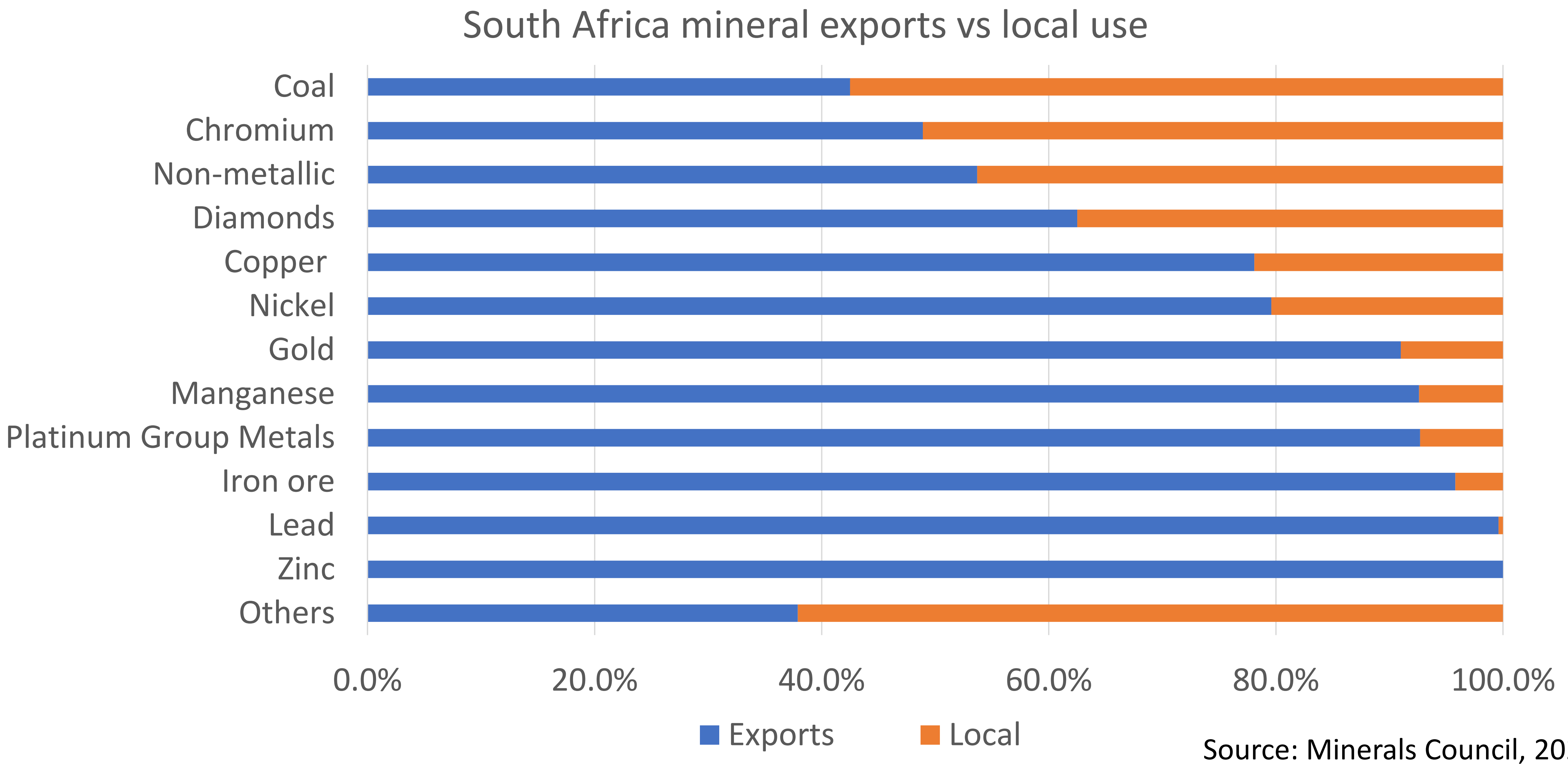
Strategic minerals for a low carbon future

# South Africa’s mineral landscape




USGS, 2020; Minerals Council, 2020

# South Africa's mineral landscape




Source: Minerals Council, 2021

# Research Questions

Stage 1: Refining the focus of the research

# SA’s potential for materials for a low-carbon future

## Key Questions

- How do we leverage SA’s mineral potential for “critical materials” for the energy transition to create more local value chains?
- How do we identify the beneficiation options and industry capabilities using an economic complexity lens?
- What are the opportunities and barriers for increasing the beneficiation of downstream materials?

# Manganese Case Study

Stage 2: Identification of products residing in manganese value chain

# Manganese case study

- Manganese is currently categorised as a critical mineral
- Potential for use for infrastructure and energy storage (batteries)
- South Africa produces about 30% of global production and holds 40% of global reserves
- Opportunities for linkages with other mineral value chains

# The potential for manganese in a low carbon economy

Manganese ore

Currently 90% of global demand

Steel

About 5% of global demand

Battery

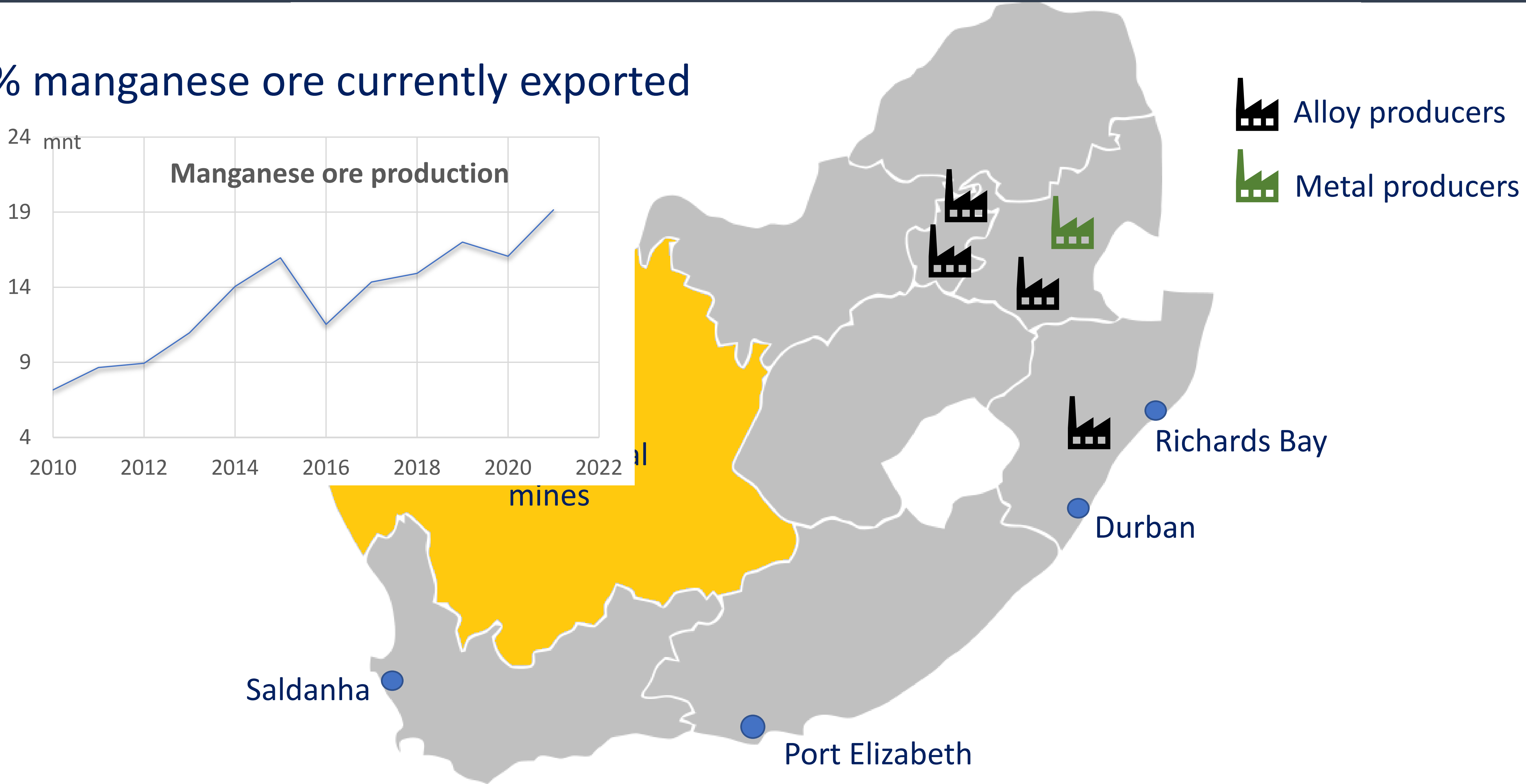
Structural steel for renewables' infrastructure e.g. wind turbines

High strength steel which is used to make lighter weight automotive and EV car bodies

Cathode in Lithium-ion batteries for EVs and energy storage

# South Africa’s Manganese industry

## 93% manganese ore currently exported



# Manganese ferroalloy industry

- 90% manganese ferroalloys produced worldwide are used in steel, consumption and production closely follow the production of crude steel.

- There are currently four producers of manganese ferroalloys in South Africa - Metalloys, Assmang, Transalloys, and Mogale Alloys.

- Manganese alloy industry faced with similar challenges as steel industry, particularly rising electricity costs.

- There is an increasing demand for High Strength Steels (HSS) from automotive and EVs industry. HSS are produced using regular low-carbon compositions strengthened with manganese (Mn).

# Manganese in the battery industry

- Manganese ore is processed into manganese compounds which are used to produce battery components.
- Manganese is specifically used in the cathode of lithium-ion batteries.
- Manganese is mostly used in high-energy nickel-manganese-cobalt lithium ion batteries

Manganese ore

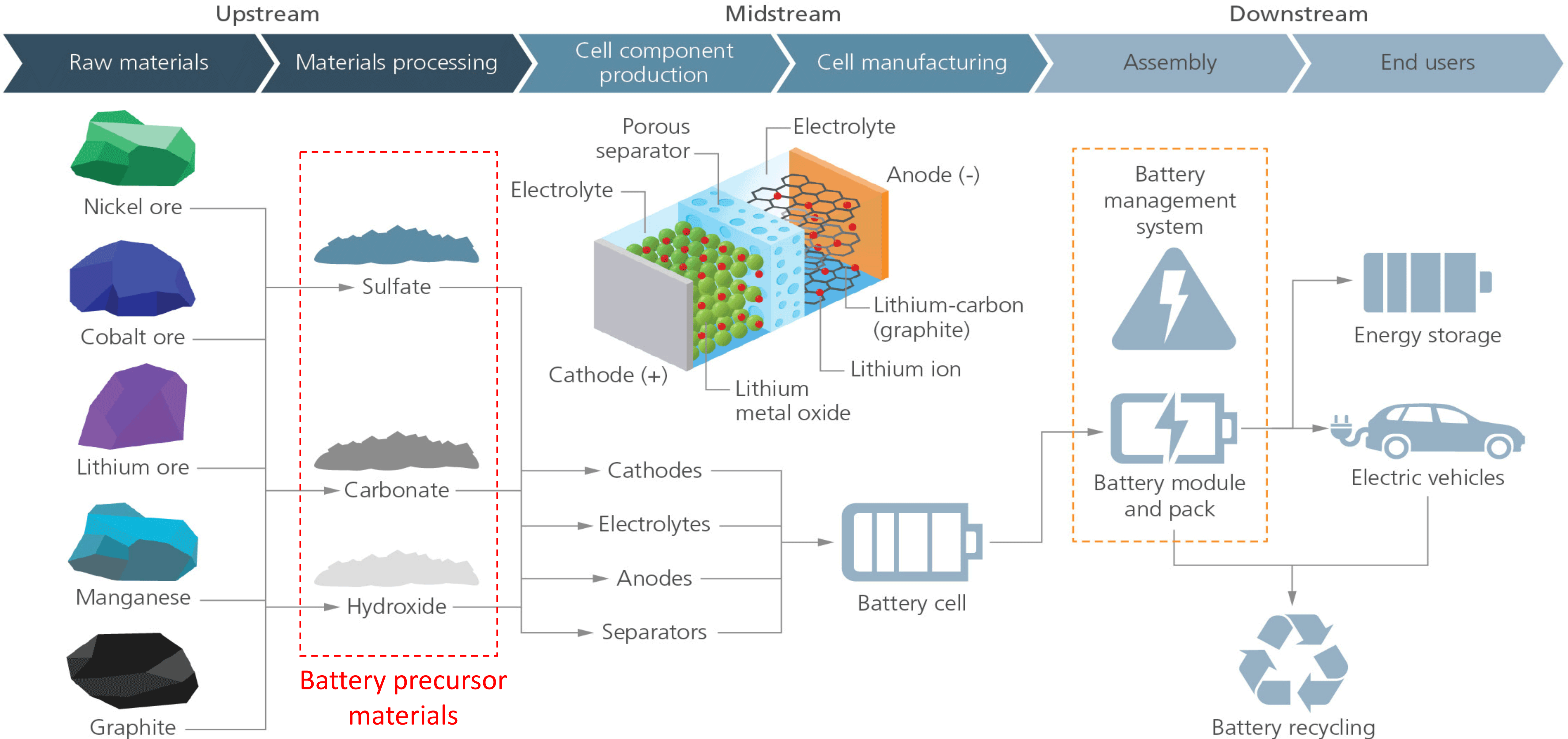
↓

Battery components

↓

Battery applications

# Battery value chain



# Current SA manganese battery industry

- There is one manganese battery compound producer, MMC (Manganese Metal Company) which is the largest EMM (electrolytic manganese) producer outside of China.

- Various manganese products are combined with other battery compounds to feed lithium-ion battery precursors value chains (mid-stream or intermediates processing).

- Global development of battery chemistries and competition highly influence  battery product routes.

# Reframing South Africa’s value chain development

- Realign beneficiation policy -  lack of major progress on beneficiation strategy.

- Need to understand product capability shift and potential for economic complexity

- Beneficiation options and potential  for lower-cost production routes

- Maximising localisation and establishing linkages with other value chains to support manufacturing growth and job creation

# Industrial Policy and Beneficiation through the lens of Economic complexity

Using Economic Complexity and Industrial Relatedness metrics to inform industrial policy in a data-centric manner

Identifying frontier manganese value chain products

# Stage 3: Mapping manganese value chain products to trade data

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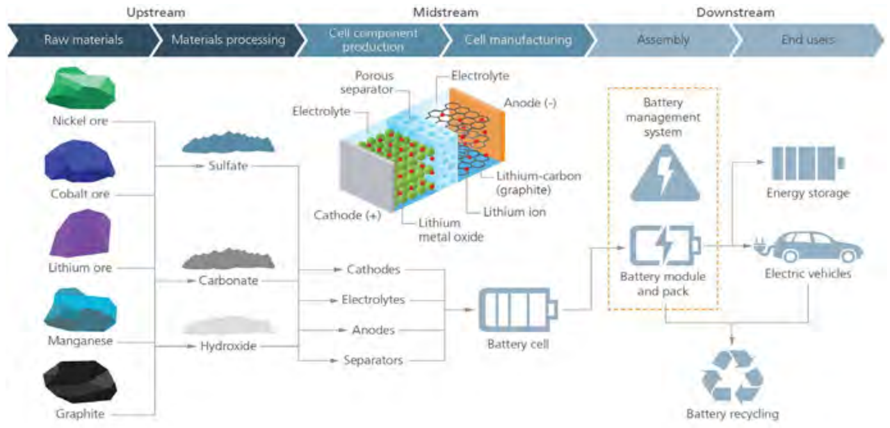
Manganese value chain flow charts




Source: L.E.K. research and analysis

Iterative mapping process

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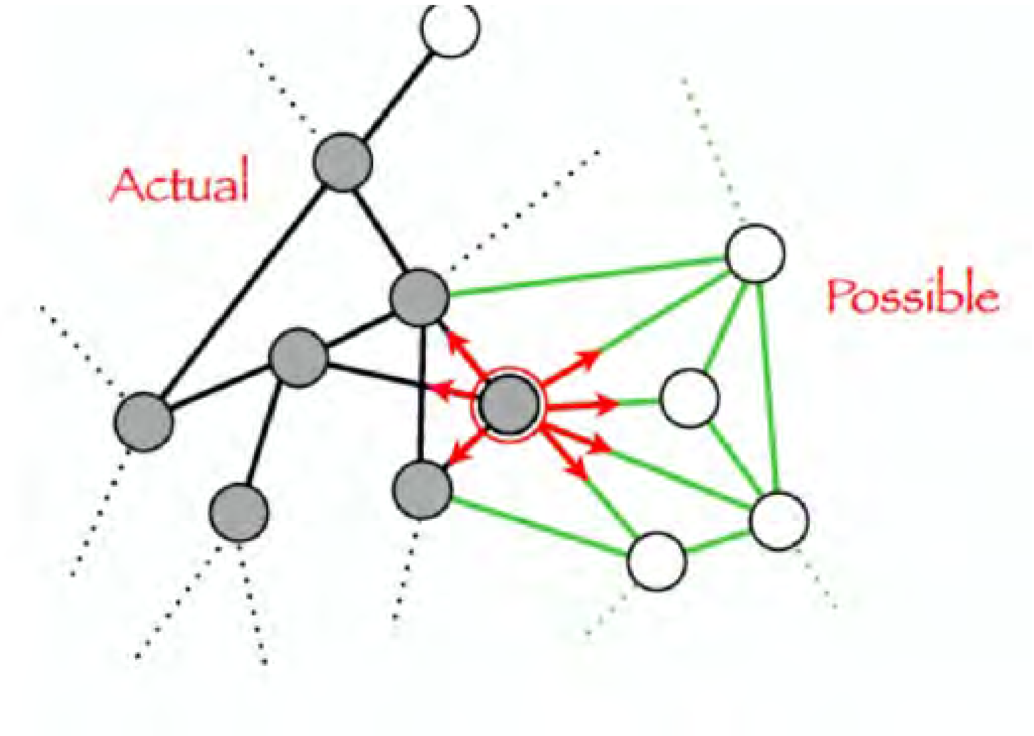
Trade data

| H06 code | Description | Direct | Indirect | Process inputs |
|---|---|---|---|---|
| 282010 | Manganese dioxide | 1 | 0 | 0 |
| 260400 | Nickel ores and concentrates | 0 | 1 | 0 |
| 280410 | Hydrogen | 0 | 0 | 1 |
| 850611 | Cells and batteries: primary, of an external volume not exceeding 300cm3, manganese dioxide | 0 | 1 | 0 |
| 871190 | Motorcycles (including mopeds) and cycles: n.e.s. in heading no. 8711, fitted with auxiliary motor, with or without side-cars: side-cars | 0 | 1 | 0 |

⋮ 61 total Mn products

# Stage 4: Applying the frontier product approach

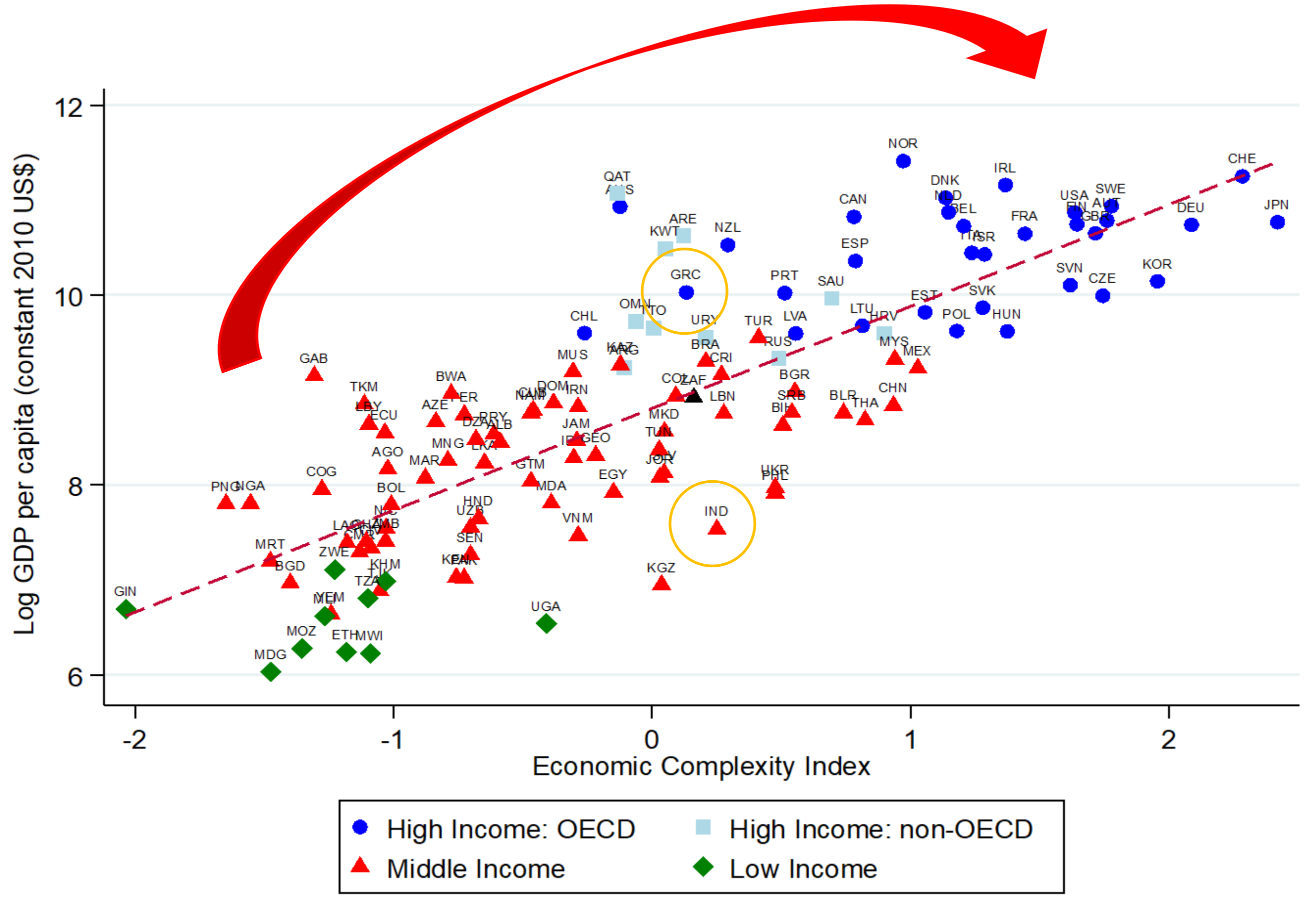



To identify frontier manganese value chain products – those that are feasible, in terms of having the capabilities to produce, and desirable, in terms of growth potential – we consult two literatures:

- Economic complexity
- Industrial relatedness

The ideas and metrics that emerge from these literatures inform industrial policy type questions in a data centric manner

# Economic Complexity (Desirability)




Source: Own calculations using trade data from BACI data (HS 6-digit revision 1992) and GDP per capita data from the World Development Indicators.

Notes: The sample of countries is reduced to those for which we estimate complexity measures.

Economic complexity metrics indirectly measure:

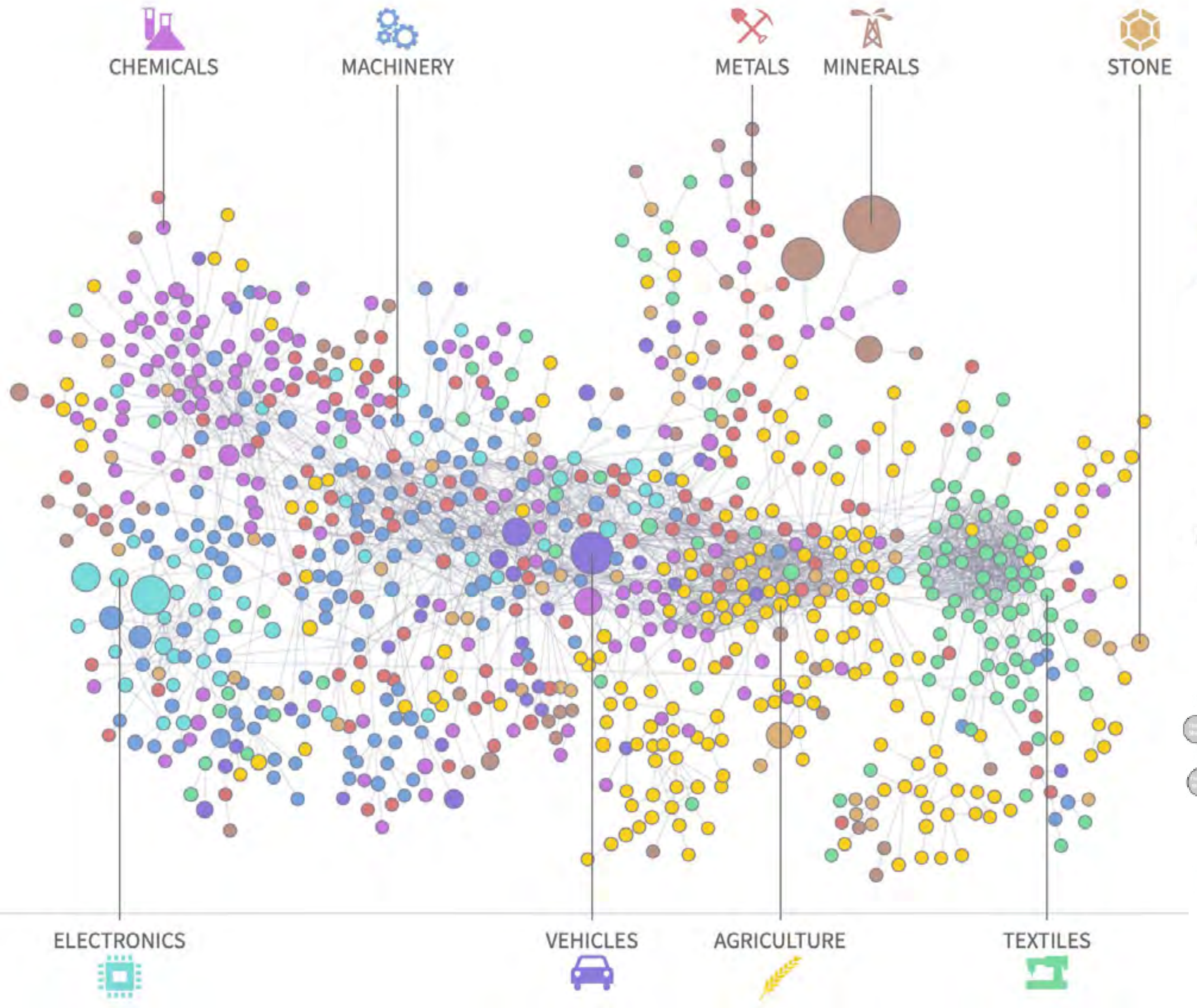
- the presence of productive capabilities, and hence, the productive capacity of an economy,
- by using information on the diversity and ubiquity of an economy's productive structure

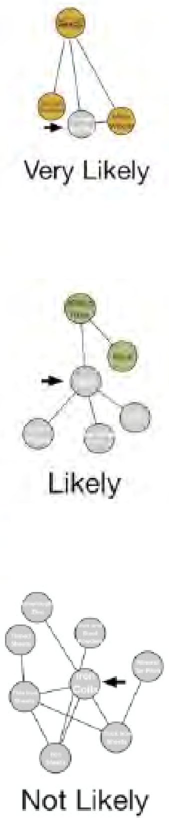
Stylized Facts:

- ECI is positively correlated with economic development
- ECI is a significant predictor of long-term economic growth
- See Hidalgo & Hausmann, 2009; Hausmann et al., 2014; Chavez et al., 2017; Christelli et al., 2015

Building economic complexity allows an economy to graduate to higher levels of economic development

# Industrial Relatedness (Feasibility)




The success of a location entering an economic activity depends on cognitive and technological proximity between the new activity and a location's prior activities.

Relatedness is indirectly measured by looking at the collocation of activities within and across locations.

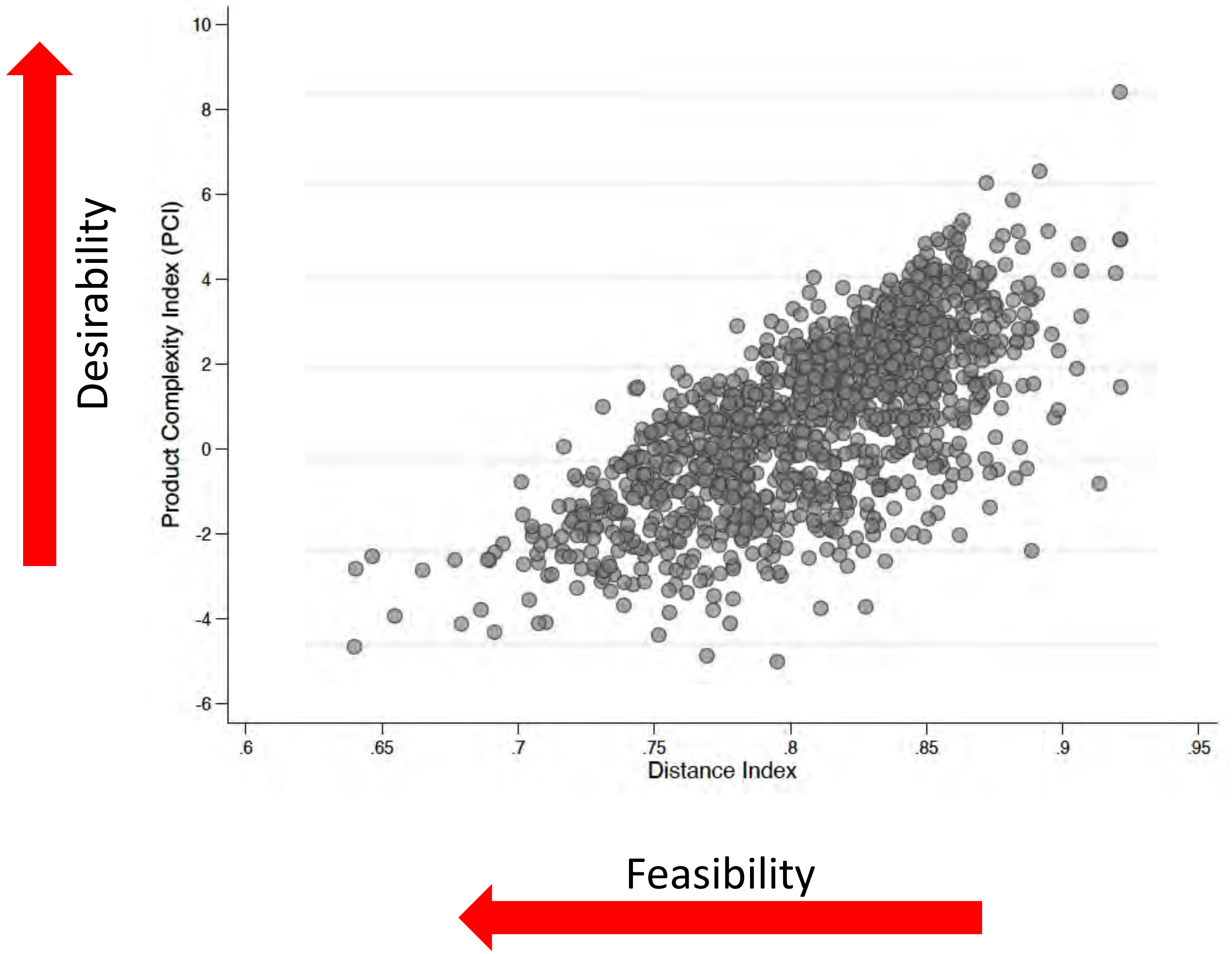
- Distance index

Stylized Facts:

- Relatedness predicts the activities (products) that a location (country) will enter or exit in the future (Hidalgo et al., 2007; Neffke & Henning, 2013)
- Structural transformation is a path dependent process (Hausmann et al., 2014)

Measures of industrial relatedness allow one to identify feasible diversification opportunities

# Frontier Product Approach: Data-Centric Lens to Inform Industrial Policy




Complexity methods help characterize detailed economic structures and provide a quantitative basis for industrial policy efforts:

- EUs Smart Specialisation Strategy (Balland et al., 2018)
- Mexico's Smart Diversification Strategy
- Canada's Supercluster Initiative
- China's Special Economic Zones (De Waldemar & Poncet, 2013)

# Frontier Product Approach: Complexity Criterion

**Frontier Product Approach A:**

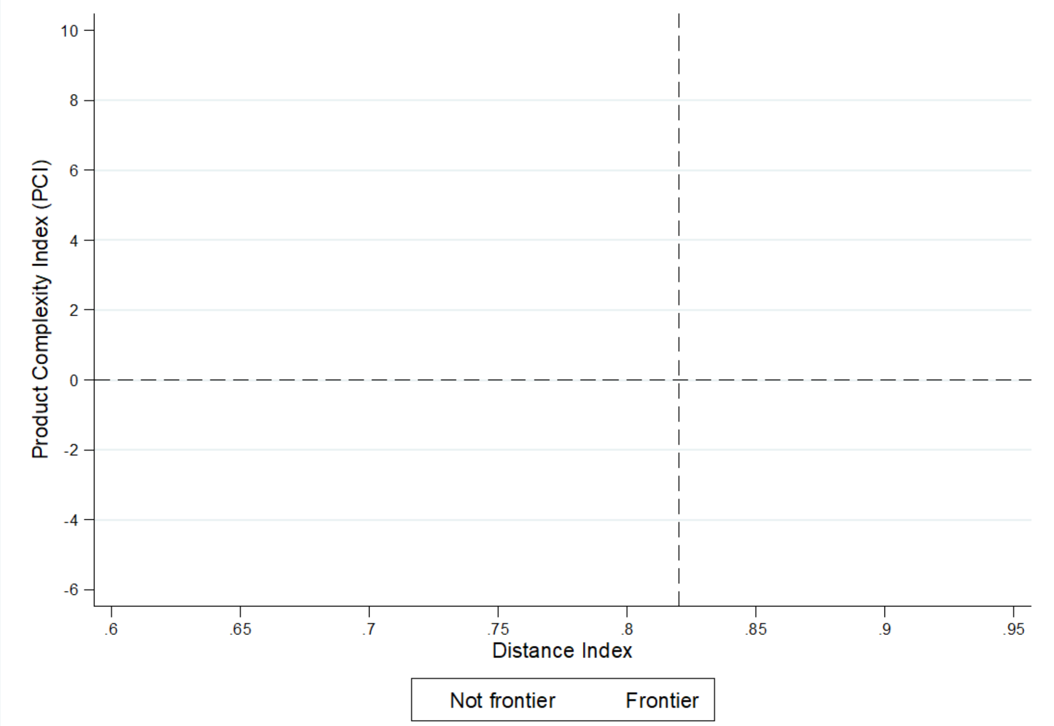
Follows Hausmann & Chauvin (2015)

Desirability criteria

- *Product Complexity Index* (PCI) > *Economic Complexity Index* (ECI)
- *Opportunity Gain Index* > 0

Feasibility criteria

- *Distance Index* < median distance of non-RCA products




**Frontier Product Approach B:**

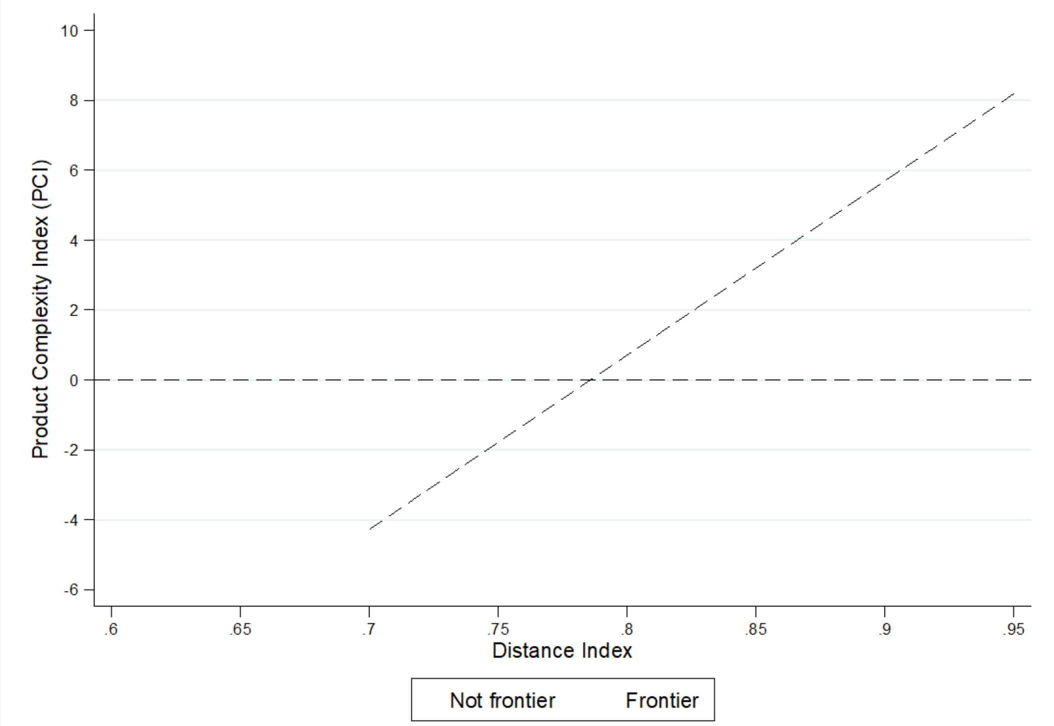
Follows Hausmann, Cunningham, Matovu, Osire & Wyett (2014)

Desirability criteria

- *Product Complexity Index* (PCI) > *Economic Complexity Index* (ECI)
- *Opportunity Gain Index* > 0

Feasibility criteria

- Take into account the trade-off between *PCI* and *Distance* and include products that are distant only if they are correspondingly complex
- The gain in complexity compensates for the substantial investment in productive capabilities needed to overcome the distance gap



# Frontier Manganese Value Chain Products

11 products

## Frontier Products: Approach A

| H06 Code | Product Description | Product Community | Type of Mn Product |
|---|---|---|---|
| 271312 | Calcined petroleum coke | Mineral products | Indirect manganese product |
| 282739 | Chlorides, nes | Chemicals & allied industries | Indirect manganese product |
| 283691 | Lithium carbonates | Chemicals & allied industries | Indirect manganese product |
| 390110 | Polyethylene having a specific gravity <0.94, i | Plastics/rubbers | Indirect manganese product |
| 390120 | Polyethylene having a specific gravity >=0.94, | Plastics/rubbers | Indirect manganese product |
| 390230 | Propylene copolymers, in primary forms | Plastics/rubbers | Indirect manganese product |
| 722820 | Bars and rods of silico-manganese steel nes | Metals | Direct manganese product |
| 740819 | Wire of refined copper of which the max cross s | Metals | Indirect manganese product |
| 750400 | Powders and flakes, nickel | Metals | Indirect manganese product |
| 841290 | Parts of hydraulic & pneumatic & other power en | Machinery/electrical | Indirect manganese product |
| 870600 | Chassis fitted with engines for the vehicles of | Transportation | Indirect manganese product |

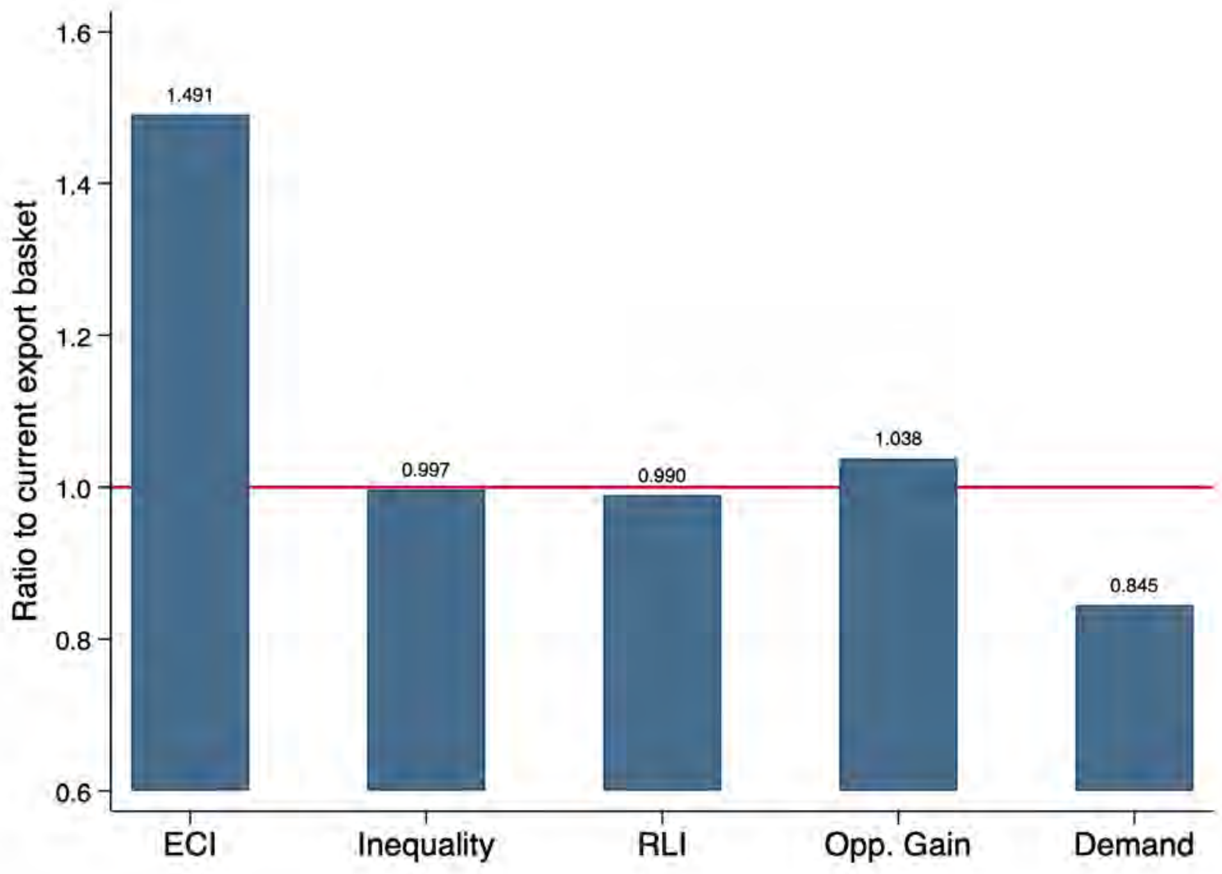
19 products

## Frontier Products: Approach B

| H06 Code | Product Description | Product Community | Type of Mn Product |
|---|---|---|---|
| 280461 | Silicon containing by weight >=99.99% silicon | Chemicals & allied industries | Indirect manganese product |
| 282520 | Lithium oxide and hydroxide | Chemicals & allied industries | Indirect manganese product |
| 282739 | Chlorides, nes | Chemicals & allied industries | Indirect manganese product |
| 283691 | Lithium carbonates | Chemicals & allied industries | Indirect manganese product |
| 380110 | Artificial graphite | Chemicals & allied industries | Indirect manganese product |
| 381800 | Chemical elements in disk form and compounds, d | Chemicals & allied industries | Indirect manganese product |
| 390110 | Polyethylene having a specific gravity <0.94, i | Plastics/rubbers | Indirect manganese product |
| 390120 | Polyethylene having a specific gravity >=0.94, | Plastics/rubbers | Indirect manganese product |
| 390230 | Propylene copolymers, in primary forms | Plastics/rubbers | Indirect manganese product |
| 390290 | Other polymers of propylene or other olefins, i | Plastics/rubbers | Indirect manganese product |
| 722820 | Bars and rods of silico-manganese steel nes | Metals | Direct manganese product |
| 722990 | Wire of alloy steel, o/t stainless | Metals | Direct manganese product |
| 740822 | Wire, copper-nickel base alloy or copper-nickel | Metals | Indirect manganese product |
| 750400 | Powders and flakes, nickel | Metals | Indirect manganese product |
| 841280 | Engines and motors nes | Machinery/electrical | Indirect manganese product |
| 841290 | Parts of hydraulic & pneumatic & other power en | Machinery/electrical | Indirect manganese product |
| 870390 | Automobiles nes including gas turbine powered | Transportation | Indirect manganese product |
| 870600 | Chassis fitted with engines for the vehicles of | Transportation | Indirect manganese product |
| 870710 | Bodies for passenger carrying vehicles | Transportation | Indirect manganese product |

# How do frontier products affect South African development?

- Assume we diversify production to produce all 19 Manganese value chain frontier products
- Relative to the current scenario, Manganese value chain frontier products have the following effect:
  - ECI and Opportunity gain increase relative to current scenario (good)
  - Inequality decreases slightly (good)
  - RLI and Global Demand indicators decrease (not so good)



# Policy calculus to aid economic development goals

- Policy makers may have different priorities – e.g., promote inclusive growth; promote labour-intensive growth; etc.
- We can model these preferences and their impact on our various indicators.
- Create indicators for complexity; opportunity gain; labour intensity; inequality; global demand; distance from current product portfolio
- Normalise indicators to all lie between 0 and 1, and then create indices where indicators are weighted according to preference:

$$Index = \sum_{i=1}^{n} w_i I_i$$

where $w_i$ are the weights and $I_i$ are normalised indicators.

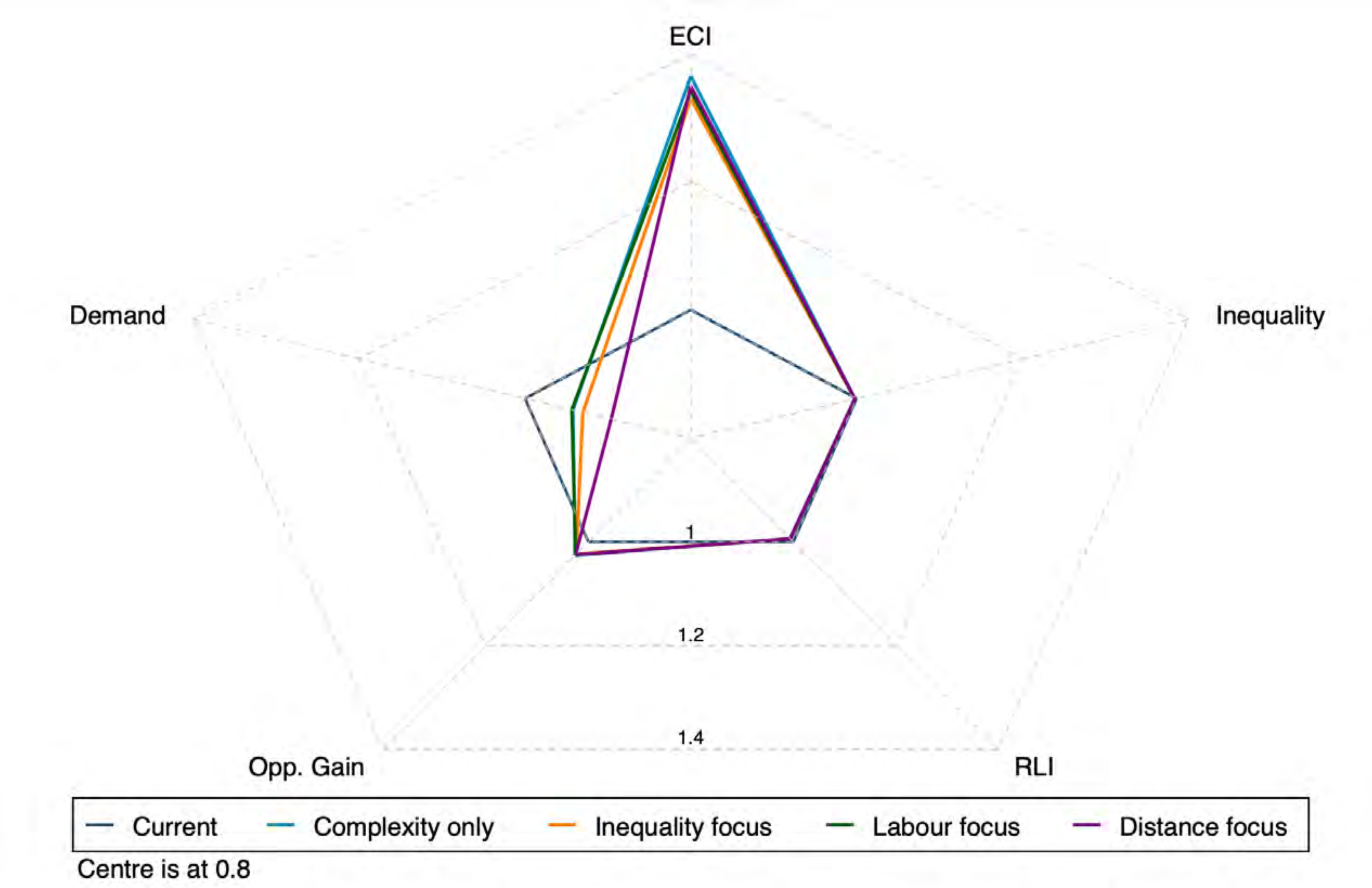
# Policy calculus: Scenarios

- We created different scenarios prioritising different agendas differently.
- These included:

1. Strategic approach (Prioritising most desirable/complex products)
2. Labour-maximizing approach (Prioritising most labour-intensive products)
3. Inclusive growth approach (Prioritising products with lowest inequality indices)
4. Pragmatic approach (Prioritising most feasible/closest products)

- In all cases, we choose the top 10 products in the list and assume RCA is achieved in those.

# Policy calculus: Results




- Results are very similar for all scenarios, except for changes in demand.
- All scenarios grow economic complexity
- All scenarios have marginal gains in opportunity gain – potential for future diversification.
- RLI and inequality both decrease, but very marginally.

# Opportunities and Challenges

Step 5: Techno-economic analysis to assess the opportunities and challenges associated with manganese value chain products

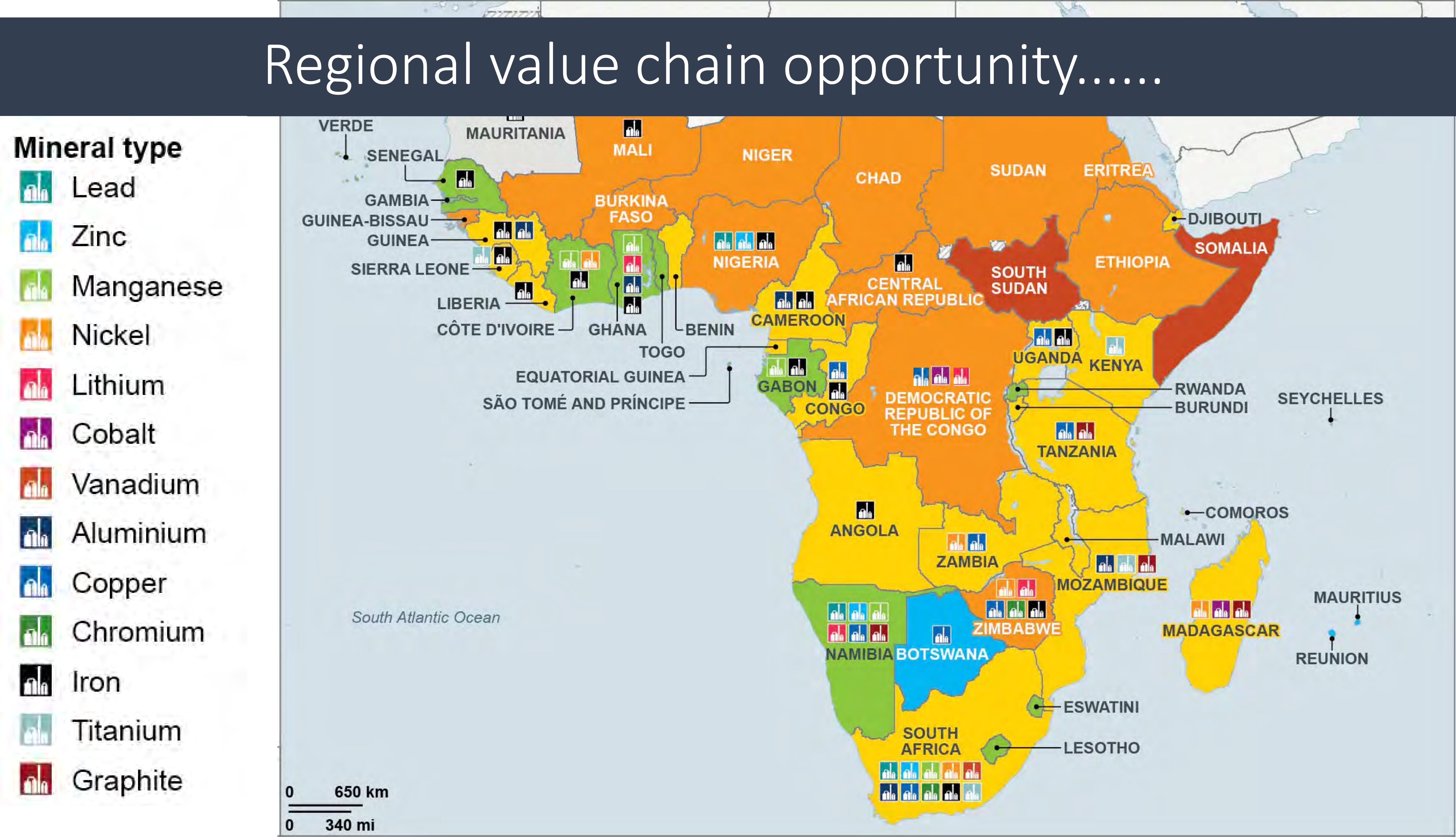
# Manganese SA steel value chain potential

| **Opportunities** | **Challenges** | **References** |
|---|---|---|
| SA's high quality manganese and iron ore grades | High local production costs (electricity and labour). Transport/logistics constraints. Global competition. | Bam and Bruyne, 2019; Van Zyl et al., 2021 |
| SA steel industry growth/support | Scaling up local capacity…rising production costs. | Steel Masterplan DTIC, 2021 |
| Expand steel products output for example - high strength steel production for EVs and automotive sector, renewable industry machinery (windmills?, etc.) | In depth understanding of approach to building economic complexity to inform/support enabling policy environment. | Bam and Bruyne, 2019 |
| Potential for SA to  produce "green steel" using hydrogen, forming linkage with hydrogen valley development and metal recycling. | Technology implementation and industry integration | Steel Masterplan DTIC, 2021 |

# Manganese SA battery value chain potential

| **Opportunities** | **Challenges** | **References** |
|---|---|---|
| SA's high quality ore grades more suitable for battery producers | Limited domestic processing capacity and high local input costs (electricity and labour). | Van Zyl  et al., 2020 |
| SA is the only producer of EMM (electrolytic manganese) outside of China | Scaling up local capacity… and competition with lower-cost EMM output from China, and alternative processing routes from Australia | Moore Stephens, 2018; Van Zyl  et al., 2020 |
| Moving down the value chain and leverage strong auto industry capability | In depth understanding of approach to building economic complexity to inform/support enabling policy environment. | |
| Potential for local battery precursor production - linkages with PGM producers for by-product nickel and cobalt. Regional linkage with neighbouring countries. | Regional corporation and integration of value chains. | |

# Regional value chain opportunity……



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