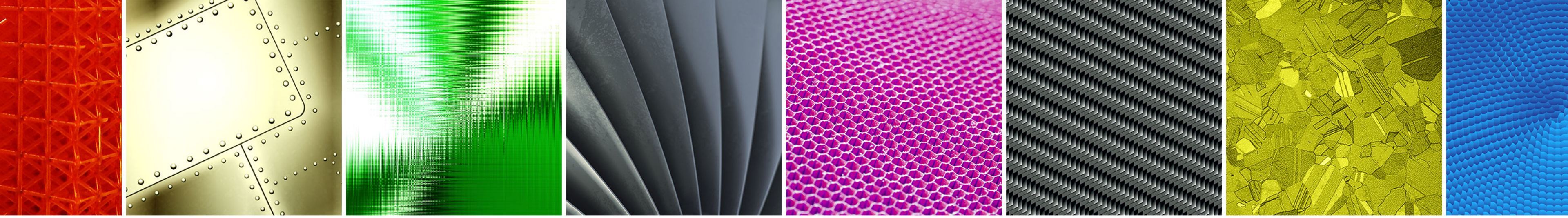

Critical, conflict and strategic materials risks

Dr. James R. J. Goddin

Collaborative Programme Manager

World Resources Forum, Workshop 9, 13th October 2015

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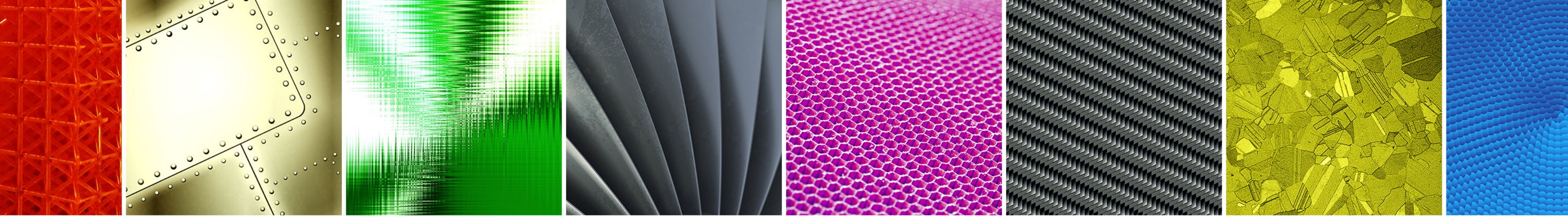
Outline

- Brief introduction to Granta Design
- What are Critical Materials?
- Product level risk assessment (SAMULET & EMIT)
- Supporting collaboration (AccMet & HITEA)
- Where next?
- Conclusions
- Questions



Brief introduction to Granta Design

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Introducing Granta Design

Our mission is to lead materials information technology –
to advance materials engineering and education,
and to enable better, greener, safer products.

We do this through…

Software + Information + Services + Network

Granta Design—innovating since 1994

UNIVERSITY OF CAMBRIDGE

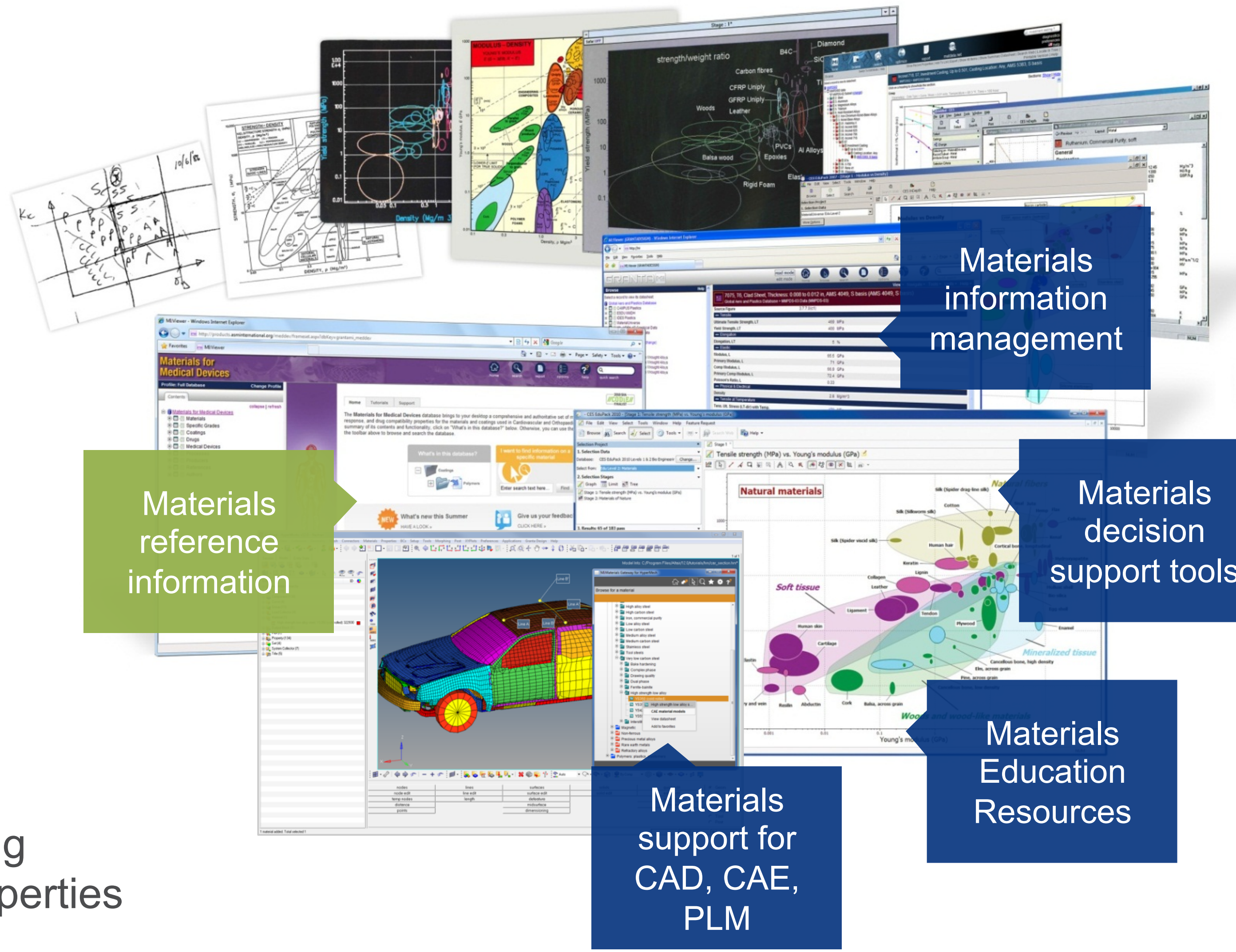
ASM INTERNATIONAL

Materials information technology is…

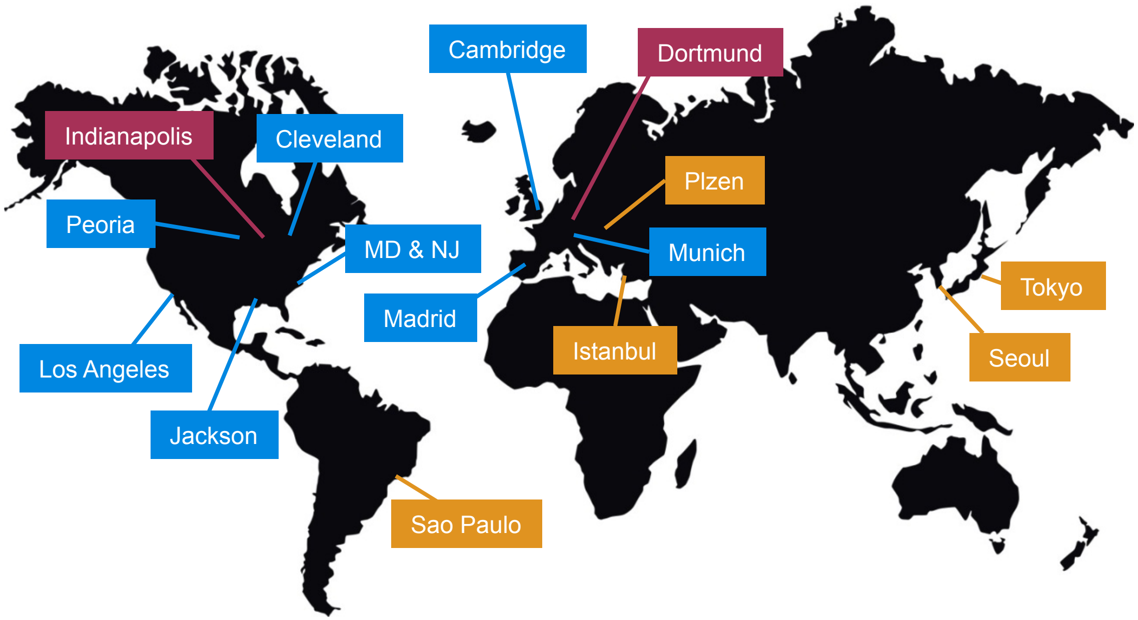
Software +

Information

…related to engineering materials and their properties



Our company and network



130 Granta staff

- The world's largest team solely focused on materials information technology
- Materials experts, software engineers, education specialists…

Network

- Hundreds of implementations in industry worldwide
- Three major collaborative Consortium projects
- 1,000+ universities using Granta's teaching resources
- Partnerships and collaborations with technology leaders
- Sales & service partners enhance worldwide service

Services

- Uniquely experienced materials information management implementation team
- Specialist Service partners
- Services including product support, training, consultancy…

Our network: consortia and example customers

Consortia

- Material Data Management Consortium
- EMIT Consortium
- AutoMatIC

Airbus
Airbus Helicopters
Airbus Defence & Space
AWE
ASCO Industries
Baker Hughes
Boeing
Bombardier Aerospace
Bosch
Constellium

DePuy
Donaldson
Doosan Babcock
Embraer
Emerson Electric
ESA
Ethicon Surgical Care
GE
General Motors
GKN Aerospace

Honeywell
Huntsman
Hutchinson
IHI
Jaguar Land Rover
KSPG
Lab 126 (Kindle)
LL Products
Lockheed Martin
MASCO
MBDA Group
MTU
NASA
Northrop Grumman
Novo Nordisk
NPL
Philips Technologie

Parker Aerospace
Perkins Engines
Pratt & Whitney
PSA Peugeot Citroën
Raytheon
Rheinmetall (KSPG Auto)
Rhodia
Rolls-Royce
RUAG Space
Suzlon
Sulzer
Thales
Thyssen Krupp Steels
TRW Automotive
United Technologies Corp
Vestas

Our network: example partners and collaborations

Owners

University of Cambridge

ASM International

Software

Altair | ANSYS | Autodesk | Dassault Systemes | PTC | Siemens

Data

ASME Setting the Standard | CAMPUS | Global Powder Metallurgy Property Database | IHS | M-Base Engineering + Software | MI-21 Metals Information For the 21st Century

MMPDS | NCAMP | NIMS | Stahl | UL

Computation

CMDNetwork

Collaborations

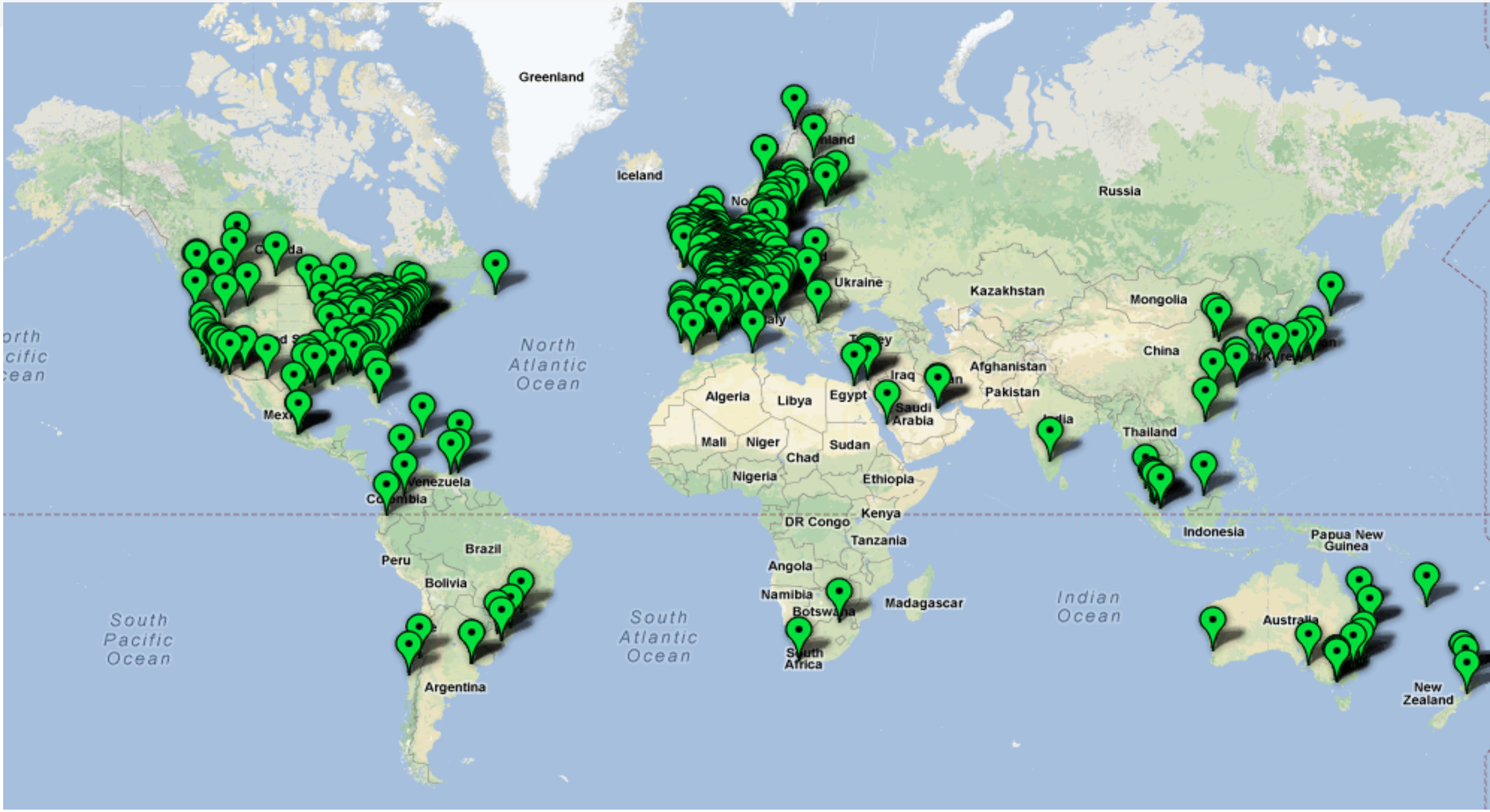
ADS | AMAZE | Accelerated Metallurgy | Ellen MacArthur Foundation The Circular Economy 100

Education

SEFI

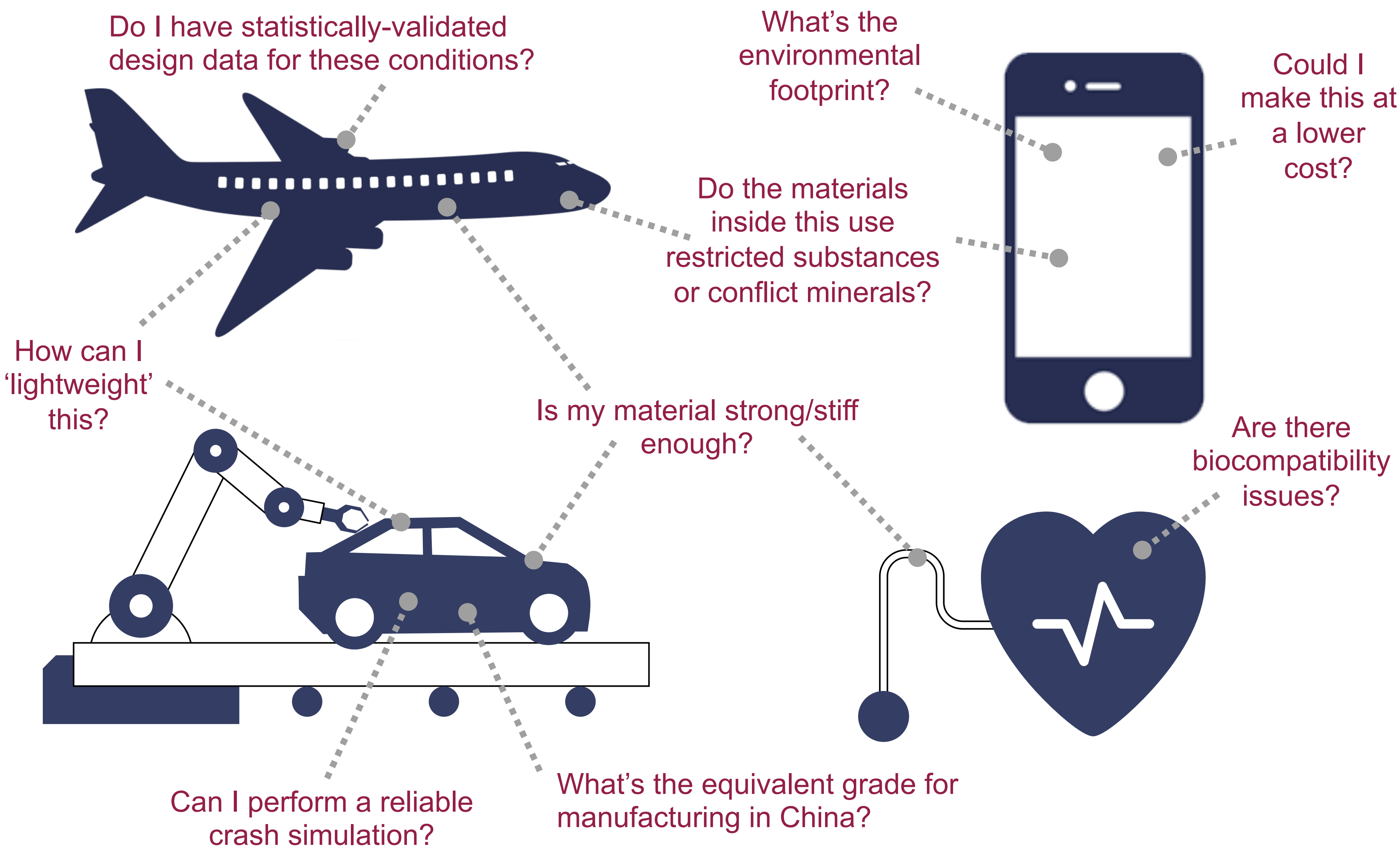
FEMS

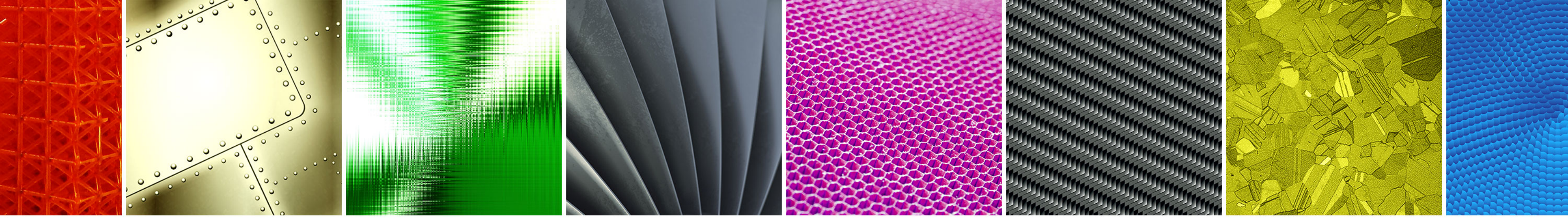
Our network: CES EduPack



Over 1,000 Universities and Colleges

Why does materials information matter?





What are critical materials?

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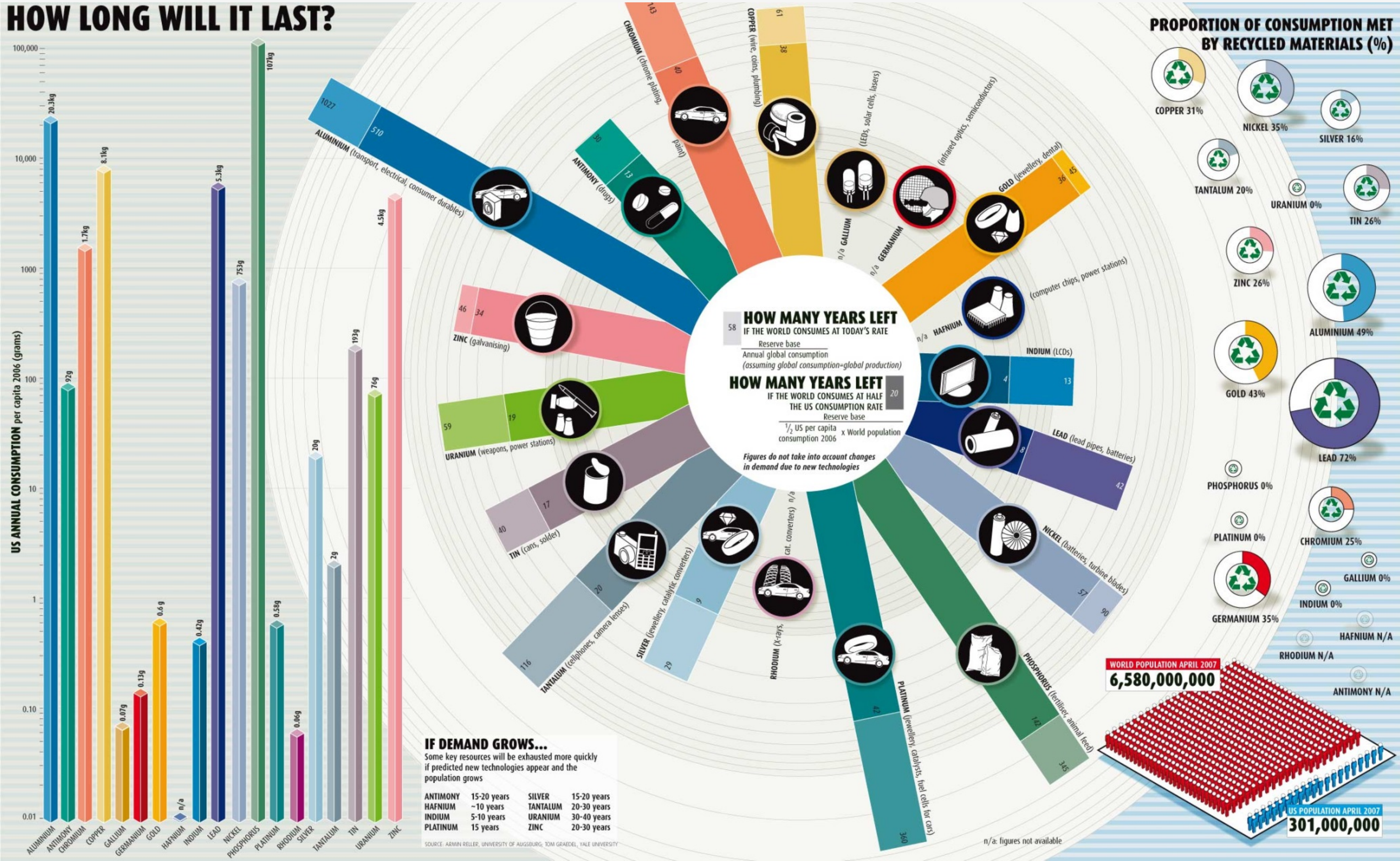
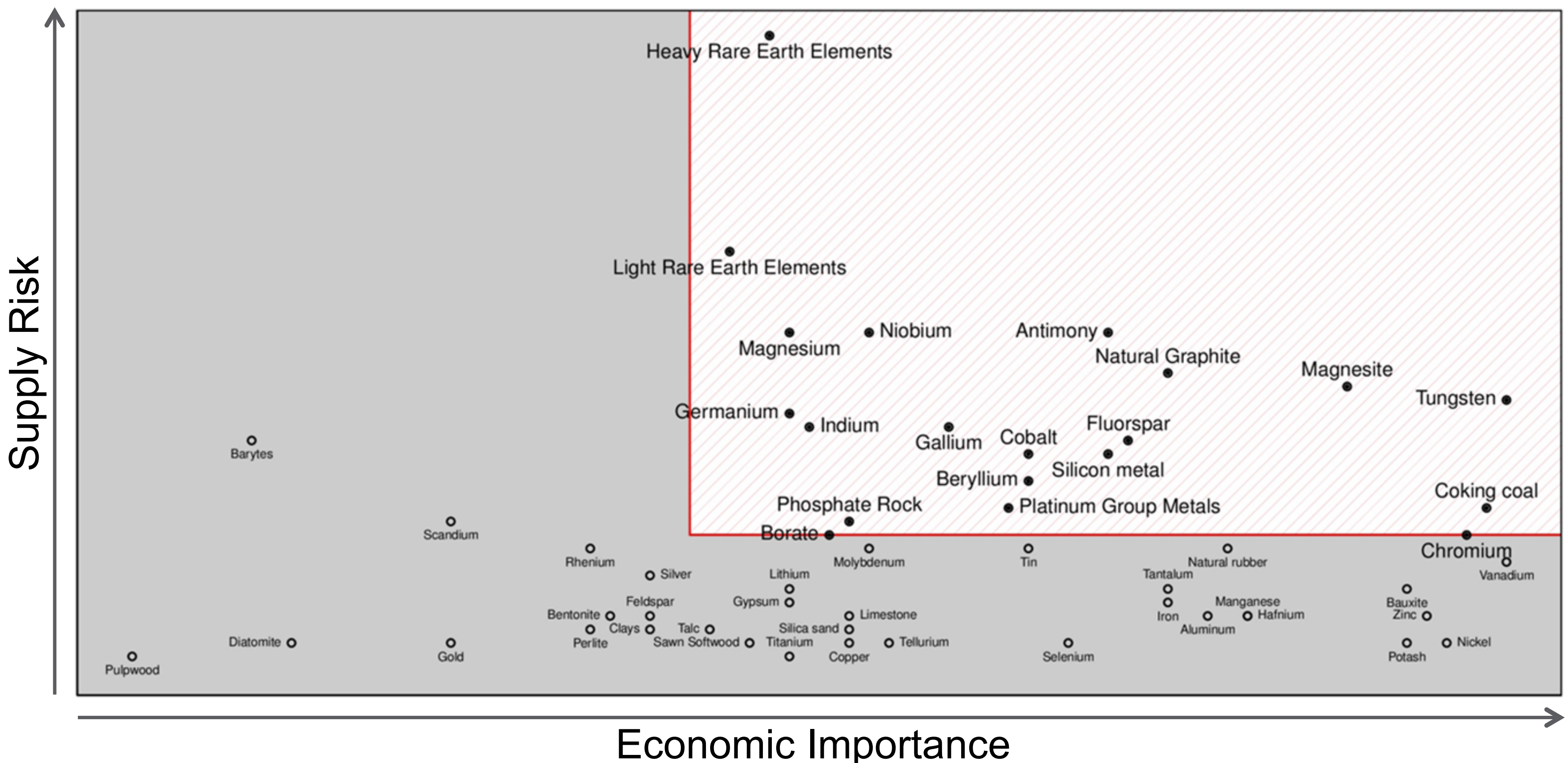
Materials we're going to run out of?



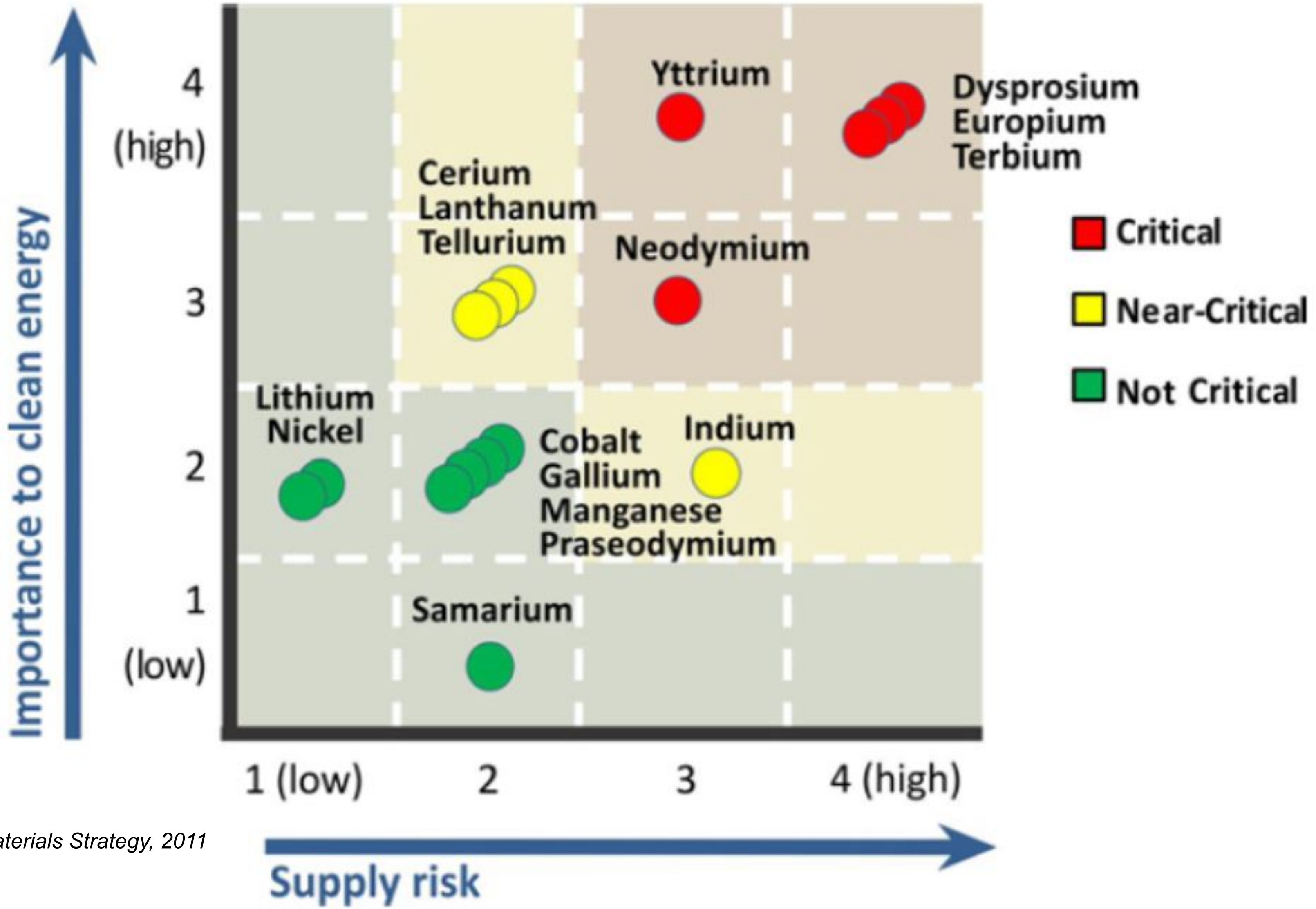
Armin Reller, University of Augsberg & Tom Graedel, Yale

Materials on this list?



Critical Raw Materials – European Commission

Or on this list?



US DoE, Critical Materials Strategy, 2011

Or on this list?

British Geological Survey

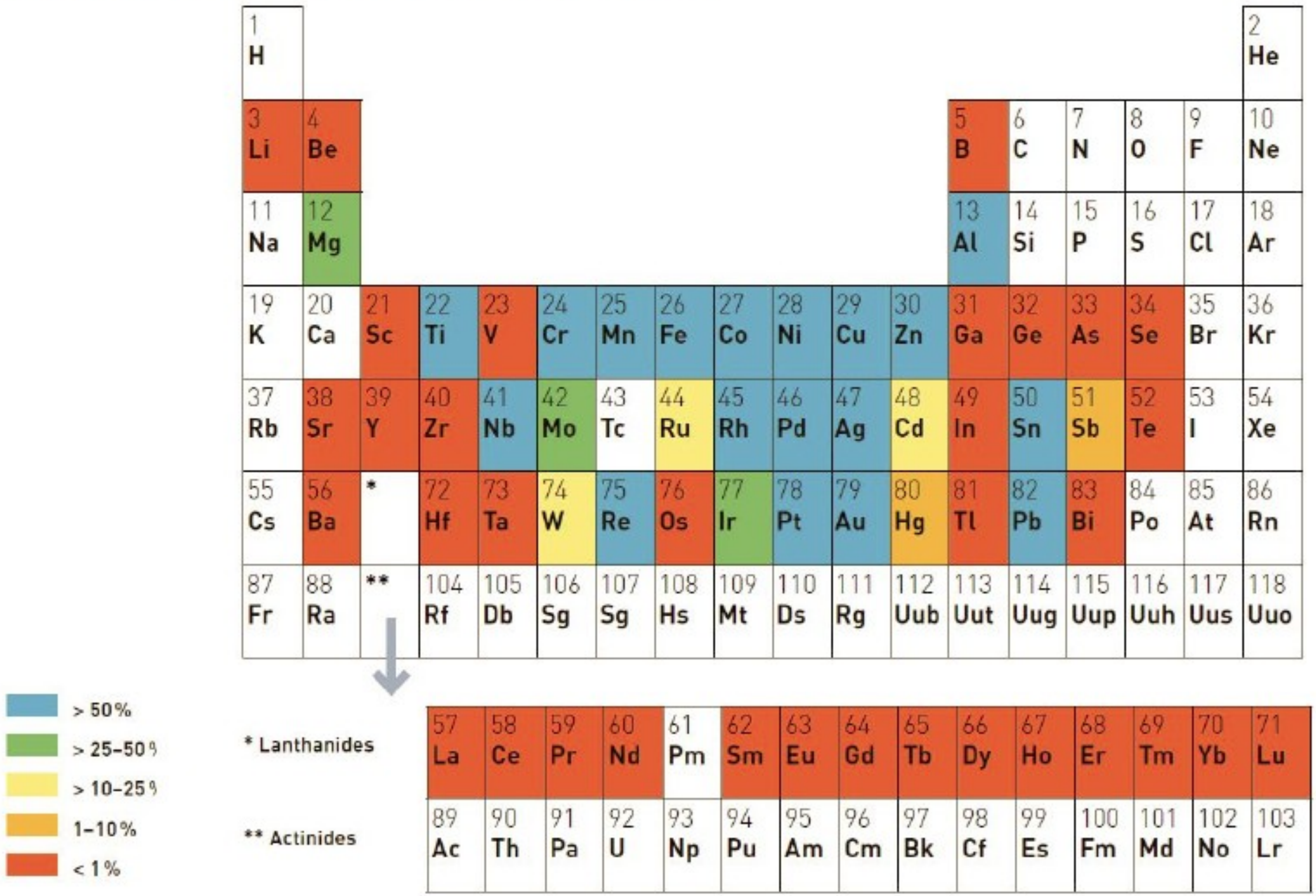
Risk list 2012—Current supply risk index for chemical elements or element groups which are of economic value

Element or element group	Symbol	Relative supply risk index	Leading producer	Top reserve holder
rare earth elements	REE	9.5	China	China
tungsten	W	9.5	China	China
antimony	Sb	9.0	China	China
bismuth	Bi	9.0	China	China
molybdenum	Mo	8.6	China	China
strontium	Sr	8.6	China	China
mercury	Hg	8.6	China	Mexico
barium	Ba	8.1	China	China
carbon (graphite)	C	8.1	China	China
beryllium	Be	8.1	USA	Unknown
germanium	Ge	8.1	China	Unknown
niobium	Nb	7.6	Brazil	Brazil
platinum group elements	PGE	7.6	South Africa	South Africa
colbalt	Co	7.6	DRC	DRC
thorium	Th	7.6	India	USA
indium	In	7.6	China	Unknown
gallium	Ga	7.6	China	Unknown
arsenic	As	7.6	China	Unknown
magnesium	Mg	7.1	China	Russia
tantalum	Ta	7.1	Brazil	Brazil
selenium	Se	7.1	Japan	Russia
cadmium	Cd	6.7	China	India
lithium	Li	6.7	Australia	Chile
vanadium	V	6.7	South Africa	China
tin	Sn	6.7	China	China
fluorine	F	6.7	China	South Africa
silver	Ag	6.2	Mexico	Peru
chromium	Cr	6.2	South Africa	Kazakhstan
nickel	Ni	6.2	Russia	Australia
rhenium	Re	6.2	Chile	Chile
lead	Pb	6.2	China	Australia
carbon (diamond)	C	6.2	Russia	DRC
manganese	Mn	5.7	China	South Africa
gold	Au	5.7	China	Australia
uranium	U	5.7	Kazakhstan	Australia
zirconium	Zr	5.7	Australia	Australia
iron	Fe	5.2	China	Australia
titanium	Ti	4.8	Canada	China
aluminium	Al	4.8	Australia	Guinea
zinc	Zn	4.8	China	Australia
copper	Cu	4.3	Chile	Chile

Or from this area?

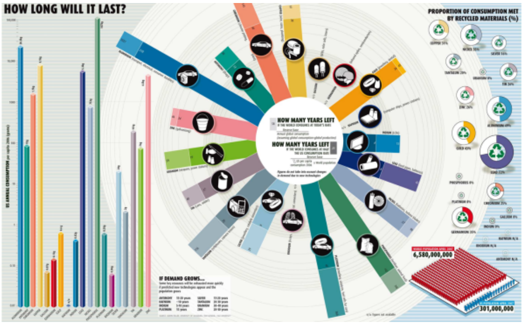
Materials we don't recycle much of?

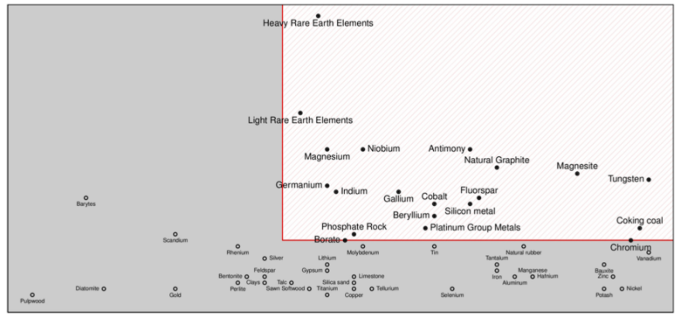
Figure 2: End-of-life recycling rates for sixty metals[3]

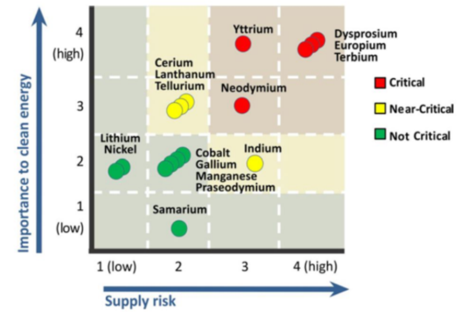


Source: International Resource Panel

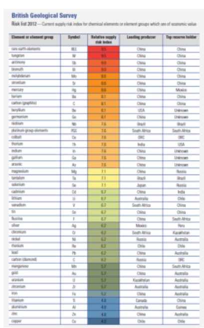
What are critical materials?

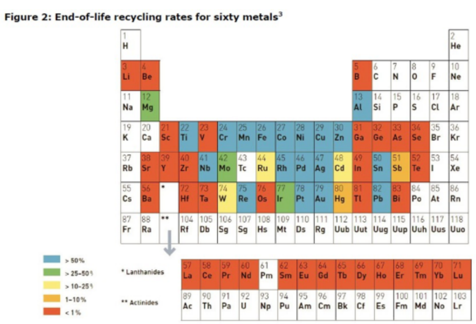






Most studies focus on global, or regional, criticality (Supply risk vs Impact)





Reflect impacts that are global/regional and for economies/sectors

What are critical materials?

Dominant approach is:

1. Identify which materials are constrained (Supply Risk).
2. Identify which sectors are impacted by constraint (Impact).

✓ Good approach to identify need for policies at a regional level.

✗ Doesn’t help industry very much – i.e. doesn’t answer:

- Which elements do we use?
- Where are they in our products?
- In what quantity do we use them?
- What is the risk and how concerned should we be?
- Do we have an alternative?
    - How much will it cost?
    - How will substitution impact our product performance?
    - How much risk does the alternative have?
    - What effect will a substitution have upstream?
- If we don’t have an alternative:
    - How else can we mitigate our risk?

Drivers for product level assessment

Access to Resources

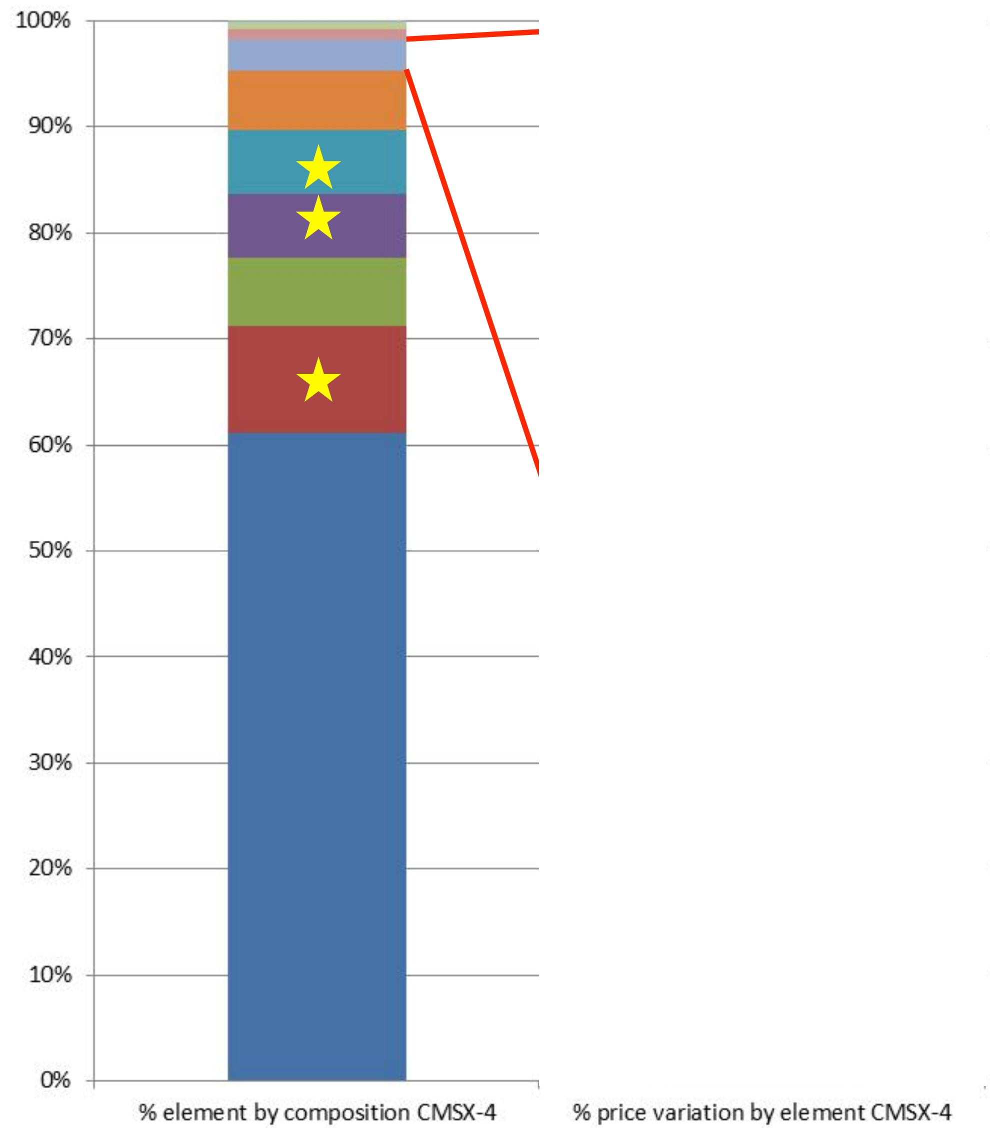
Industry concerns over existing methodology

- **The 14 materials identified in the EU report are being used as a de-facto list of "critical" materials for all industries**
  - Can give a "false negative" as the impact part of this assessment was carried out at an EU level
  - Ideally, the impact of a supply disruption needs to be assessed at a business and then sector level to establish 'critical resources' for specific industries
  - This will generate more applicable lists for assessing risks
- **Criticality lists can change depending on method used**
- **Factors important to understanding likelihood are missing or inappropriate**
  - Demand scenarios
  - Sustainability of extraction
  - Substitutability

ADS

Source: ADS Design for Environment Working Group, 2012

Example



Rhenium:
3% of composition
80% of price variation

What are Critical Materials – Industry View

- Critical materials are:
  - Any material we use which is essential to the performance of our product; and where
    - A potential for supply chain disruption exists; and
    - The likely impacts of a supply chain disruption would significantly impact our ability to:
      - Produce our product at the volumes we require
      - Sell our product competitively
      - Comply with relevant legislation

- Not all supply chain risks concern everyone:
  - We want to choose which risks to consider
  - We want to understand the context of each risk to make appropriate decisions.
  - We will decide how '*economically significant*' an element is to our business.
  - We will decide how '*substitutable*' a material is for our product.

Product level risk assessment

SAMULET & EMIT

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Starting points

- Product centric approach:
  - Understand what is in each product
    - Requires knowledge of materials and manufacturing processes
  - Assessment needs to be quick
    - Dealing with products that may have thousands or even millions of parts
  - Need to identify possible substitutes
    - Needs tools for collaboration on materials development.
    - Ability to screen possible alternatives during development
- Robust data:
  - Consider everything as a potential risk
    - Risks are business/product specific and change with time
  - Background data used needs to be as complete as possible.
    - Needs ability to fill gaps in knowledge with generic information
  - Data needs to be transparent and updatable.
    - Supply risks change
    - Products evolve
- Focus on Risk not Environment

Specific ‘Product Risks’ of concern to Industry

- Environmental
  - Energy
  - CO_2
  - Water
- Legislative
  - Restricted substances (e.g. REACh, RoHS…)
  - Conflict Minerals Legislation (e.g. Dodd-Frank)
- Supply related
  - Abundance
  - Monopolistic supply
  - Geopolitical risk
  - Environmental risk
  - Price volatility / variation

Product Risk Data : A bottom up approach

- Assessments of 65 key elements linked to production data
- 8,000 substances across 80 different lists/legislations

- Critical elements
  - THE PERIODIC TABLE
    - 1. Row 1
    - 2. Row 2
    - 3. Row 3
    - 4. Row 4
    - 5. Row 5
    - 6. Row 6
    - 7. Row 7
    - 8. Lanthanides
      - 57. Lanthanum (La)
      - 58. Alpha cerium (Ce)
      - 58. Beta cerium (Ce)
      - 58. Delta cerium (Ce)
      - 58. Gamma cerium (Ce)
      - 59. Praseodymium (Pr)
      - 60. Neodymium (Nd)
      - 61. Promethium (Pm)

60. Neodymium (Nd)

Critical materials - risk levels		
Abundance in the Earth's crust	20 to 41.5	ppm
Abundance risk level	Medium	
Sourcing and geopolitical risk Herfindahl-Hirschman Index (HHI)	5.57	
Sourcing and geopolitical risk level	Very high	
Environmental country risk Herfindahl-Hirschman Index (HHI)	4.09	
Environmental country risk level	Very high	
Conflict material risk	Low	
Price volatility	1640	%
Price volatility risk	Very high	
Elemental price variation	113	GBP/kg
Herfindahl-Hirschman Index (HHI)	9130	

- Well established criticality metrics

Linking elements to materials

- Data linked to material compositions

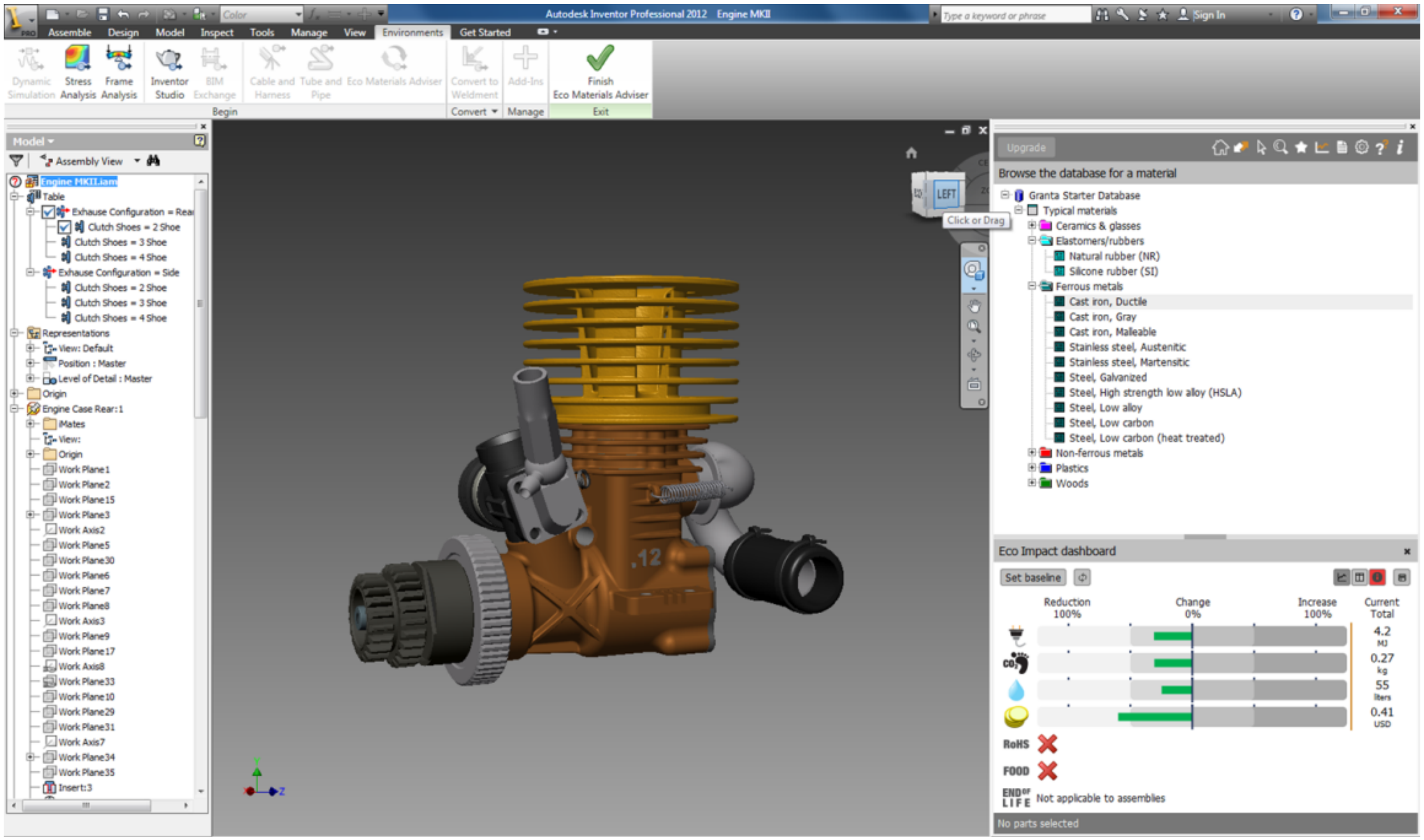
Magnesium, EZ33A, cast, T5 [v6]

Element name	Abundance risk level	Sourcing and geopolitical risk level	Environmental country risk level	Price volatility risk level
Zirconium	Low	Very low	Very low	Medium
Copper	Medium	Very low	Very low	Medium
Magnesium	Very low	Medium	Low	Low
Neodymium	Medium	Very high	Very high	Very high
Nickel	Medium	Very low	Very low	Very high

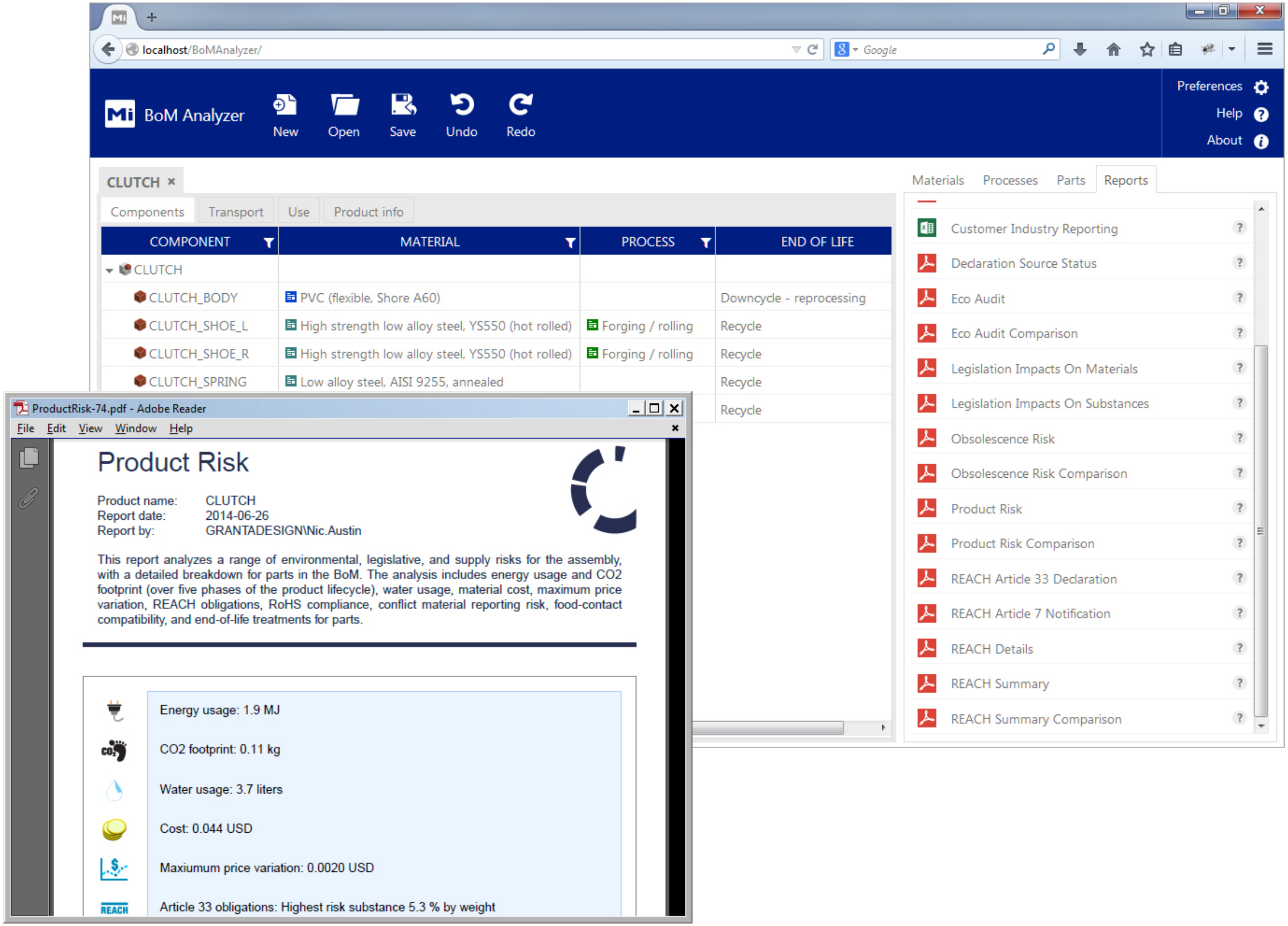
- Granta's Materials Universe database contains ~ 4,000 commercially available materials with comprehensive property data (~ 1,800 alloys).
- Highlights risks for compositions

Tools to link materials to products

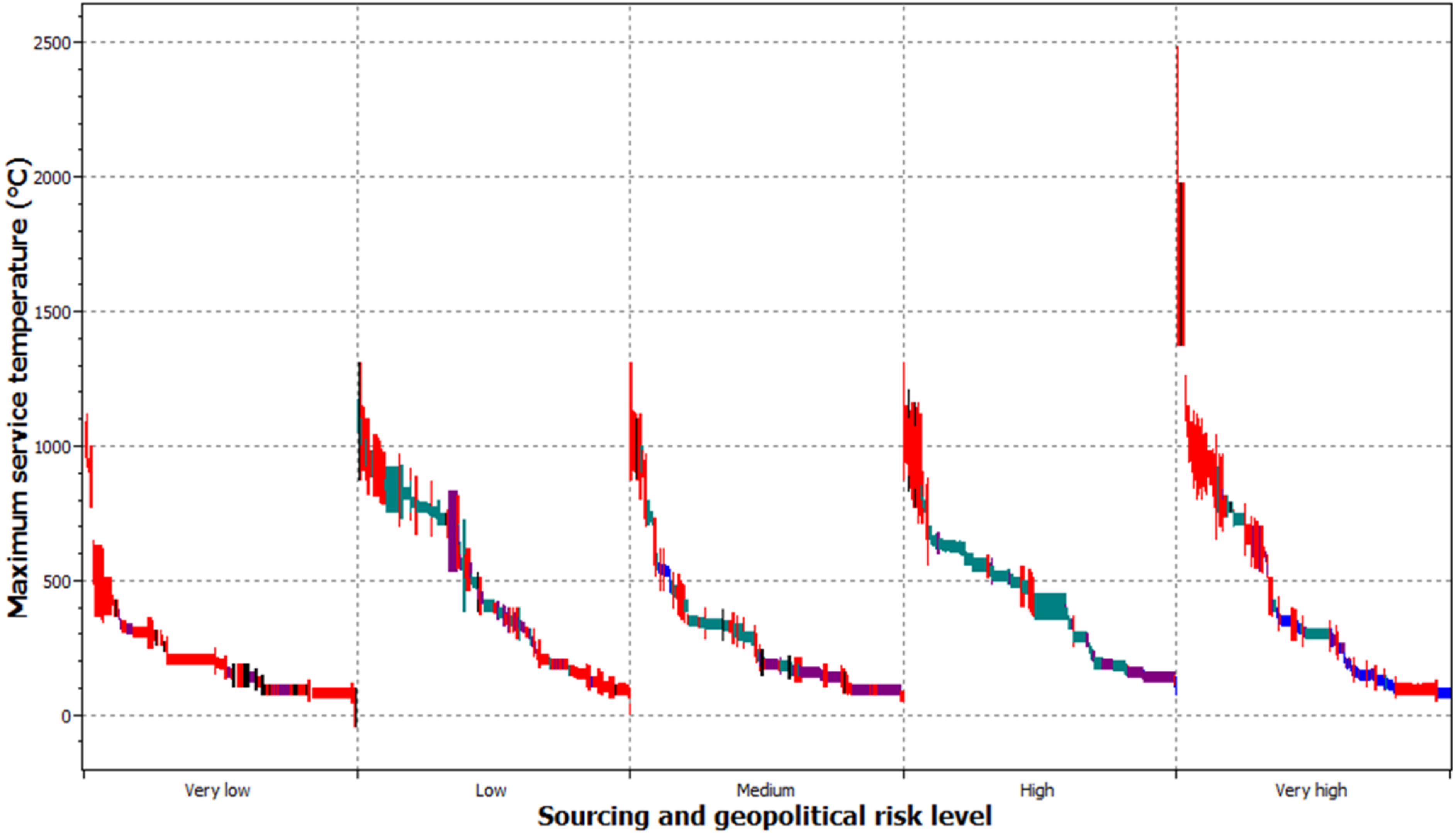
- Tools embedded within design environment highlight overall risk across all materials.



Reporting at the product level



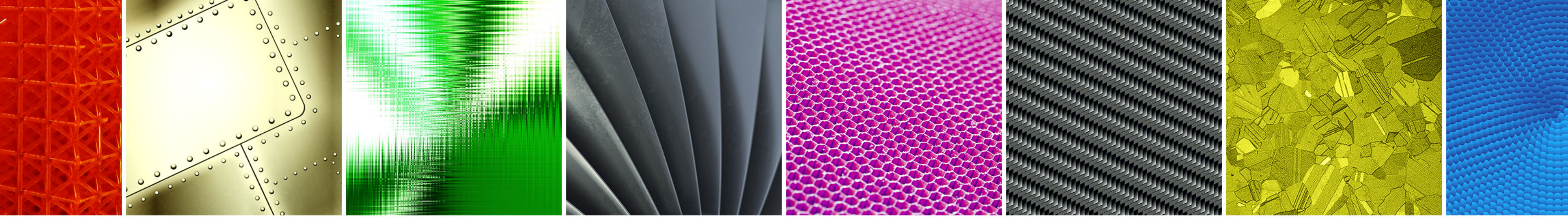
Material properties vs risk



Approach is readily extendable

- Circular Economy
  - New metric developed with Ellen MacArthur Foundation and leading partners from industry and academia.
  - Publically accessible methodology.
  - Granta have the first implementation to assess product circularity.
  - Materials containing high risk elements or with significant impacts are prime candidates for improving circularity.

[Ellen MacArthur Foundation, Circularity Indicators Project]



Supporting Collaboration

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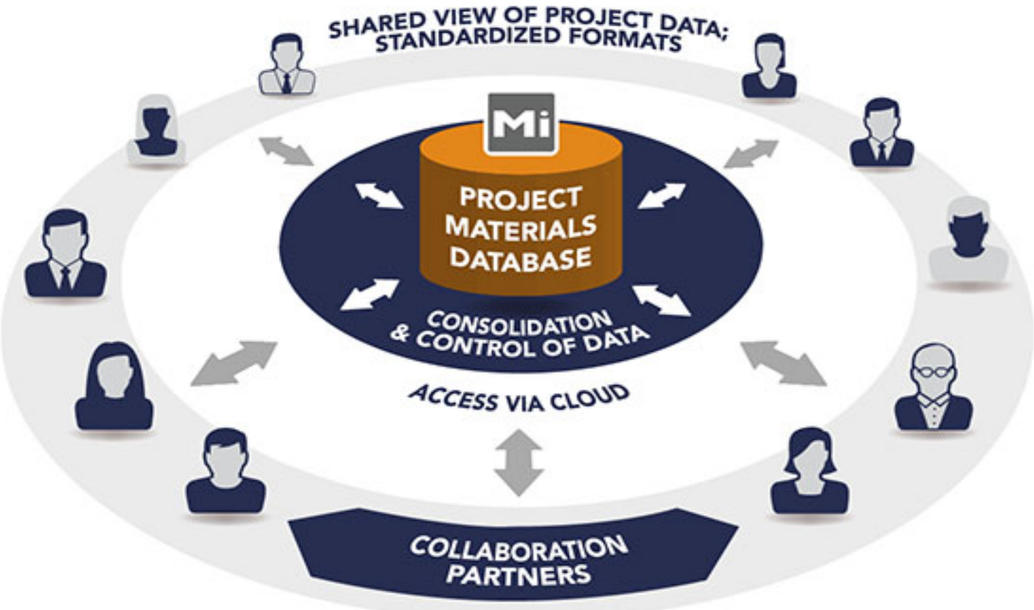
Collaborative R&D & Product Risk

- Collaboration is a key enabler in materials development
- Strong emerging need for web-based tool for materials R&D:
  - Enables effective interdisciplinary materials research
  - Captures knowledge from computational and high throughput techniques.
  - Screens candidate materials for risks during development.



[GRANTA MI:Collaborate](#)

Collaborative Data Management

Specimen tracking

Materials Simulation

Data consolidation

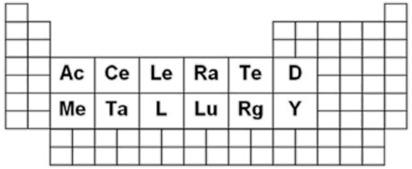
Standardisation

CONSOLIDATE DATA

Materials data from distributed partners

Automated import from test equipment

Example - Accelerated Metallurgy



28 partner EU project

Project nearing completion

Combines:

1. Large scale computational exploration of new alloys (25,000+)
2. High throughput synthesis of new alloys – 1 every 20-30 seconds.
3. High throughput and distributed testing and characterisation

All data in a shared Granta MI database, a ‘Virtual Alloy Library’

- Strong standardisation
- All data linked appropriately and automatically
- All data accessible by all partners
- All compositions screened for risk as part of R&D

HITEA

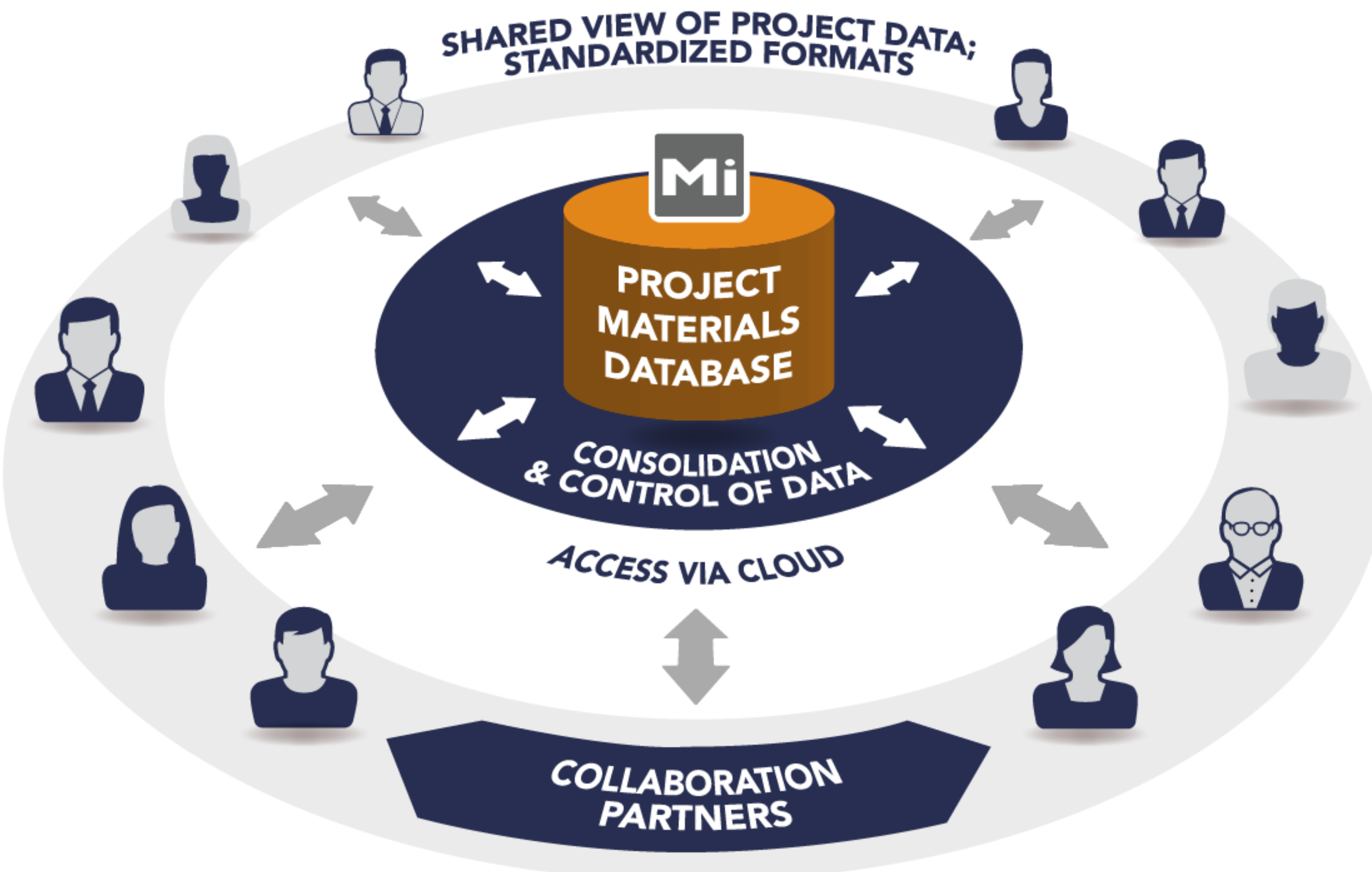
REACHing out for new materials

With hexavalent chrome recently placed on the REACH list of restricted substances, the aerospace industry is searching for replacement materials for surface treatments. David Rickerby, Head of Surface Engineering at Rolls-Royce, UK, explains how the REACH CR HITEA project is addressing the issue.

- Consortium of leading UK aerospace partners
  - Identification of substitutes to Hexavalent Chromium (REACh)
- Distributed test programme
  - Shared burden, shared benefit
  - Strong standardisation activity
  - Significant high value data

- All data collated and shared in Granta MI
  - All coating systems screened against emerging legislation
  - Identifies candidate solutions known to be subject to risk

Project experience led to GRANTA MI : Collaborate



Where next?

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A greater focus on trends

- Understanding a trend gives a lot more context
  - Has risk always been high?
  - In risk increasing?
  - Is a risk in one material balanced by a risk in another?
  - Looking at a whole product (with lots of elements) is the overall risk getting higher?
- We’ve already implemented this for price.

Substitutability

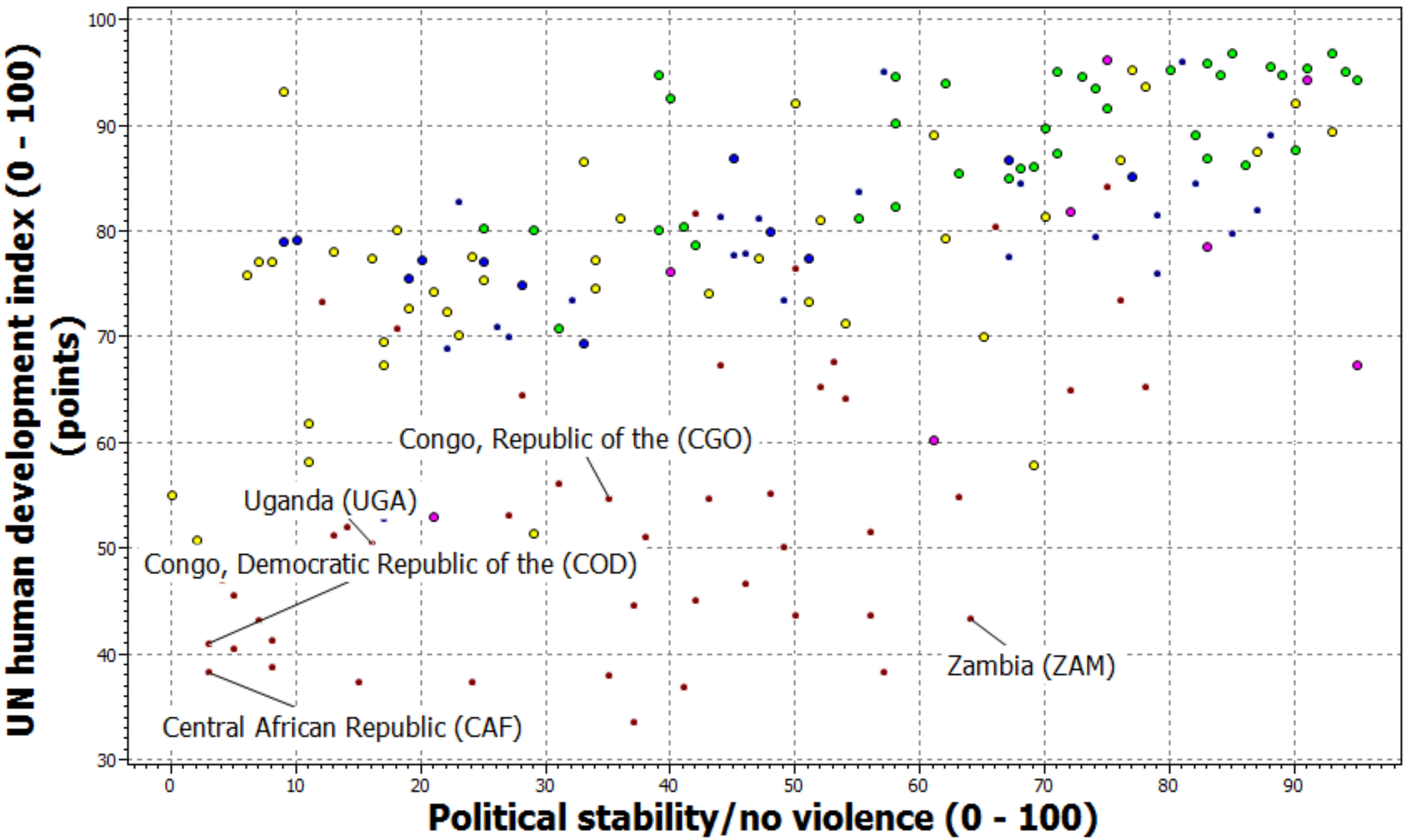
- One of the most controversial metrics to date
  - Specifically excluded from the SAMULET work
  - Traditionally evaluated by expert opinion – not very scalable/ repeatable
  - Is there a better approach?
- We think there is…
  - By taking material properties as a starting point.
  - Substitutability of an element depends on what properties you need
  - Watch this space!

Scenarios & Consequences

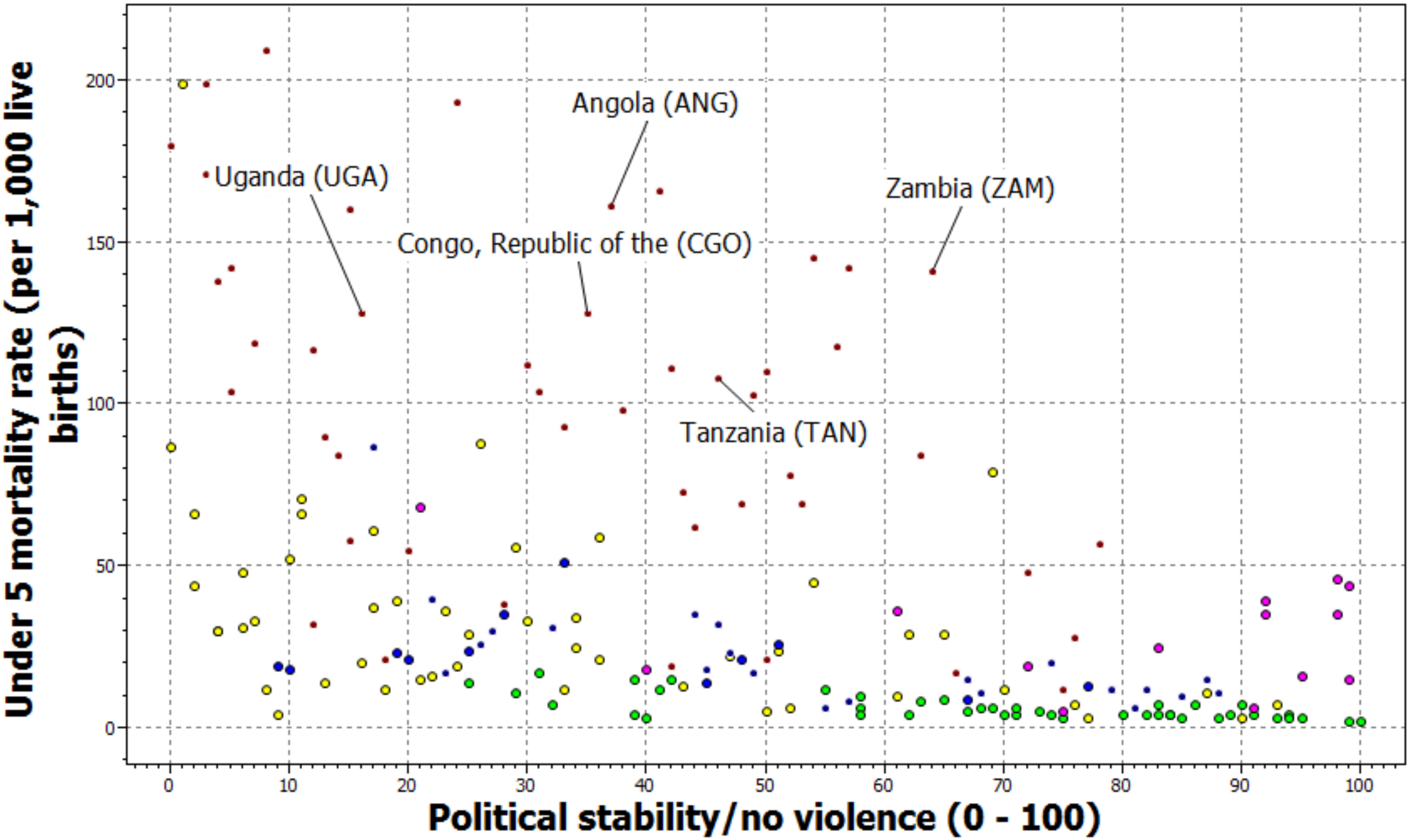
- Data used is historical:
  - Can we predict or at least model supply scenarios?
  - This requires scenarios and updated data structures & tools.
- Mitigating supply risk is difficult
  - If we succeed – what then?
- Markets are dynamic…
  - Will shifting to a new material increase demand and create a new supply constraint?
  - Will procuring from a lower risk region undermine development and increase global supply risk.
- This is a new field..

Example – Conflict Minerals

Political Stability vs. Human Development

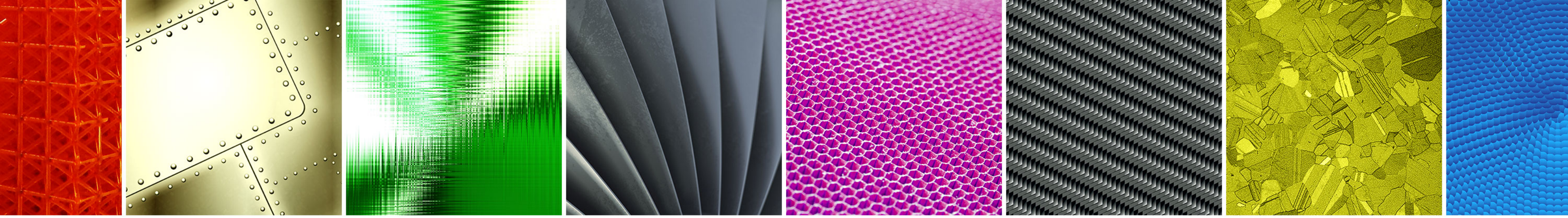


Political Stability vs Child Mortality



Conclusions

- Criticality is a shifting field.
  - Having appropriate data is essential
- The data used for regional policy making is typically not fit for engineering & design decisions.
  - Criticality is business and product specific!
  - Need to manage trade-offs.
- Research to date has asked '*What has happened?*'
- Now we need to ask '*What might happen next?*'
  - Production trends change
  - What effect will our decisions have on future supply?
  - How do we avoid inhibiting growth in emerging economies
- International collaboration is key



Questions?

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