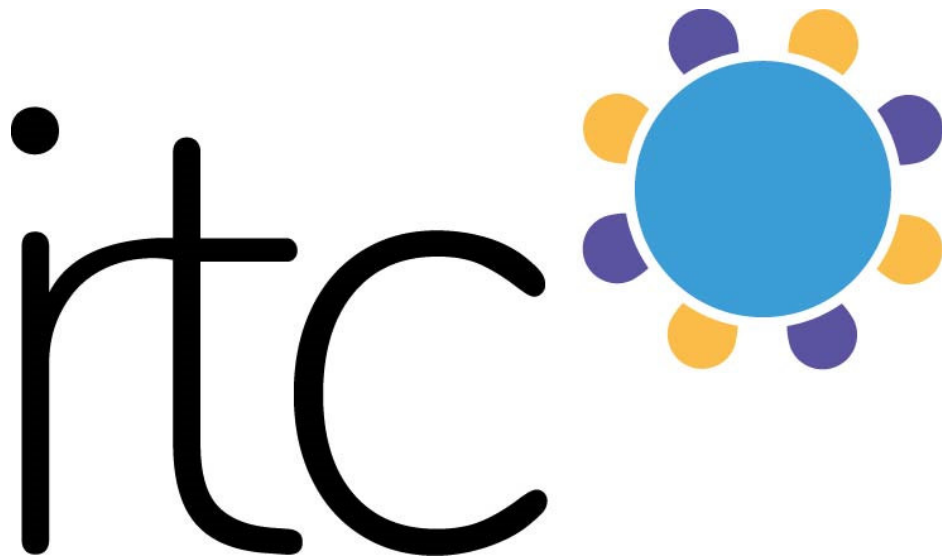


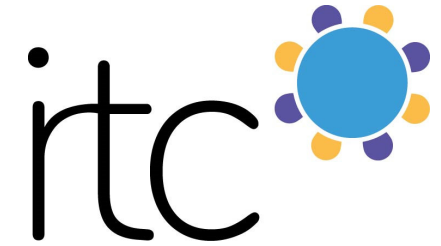
HOW METHODOLOGY DETERMINES WHAT IS CRITICAL



June 19, 2018

Resources for Future
Generations Conference,
Vancouver





Granta Product Risk



Dr. James Goddin

Market Development Manager

James.Goddin@grantadesign.com

Goal and Scope

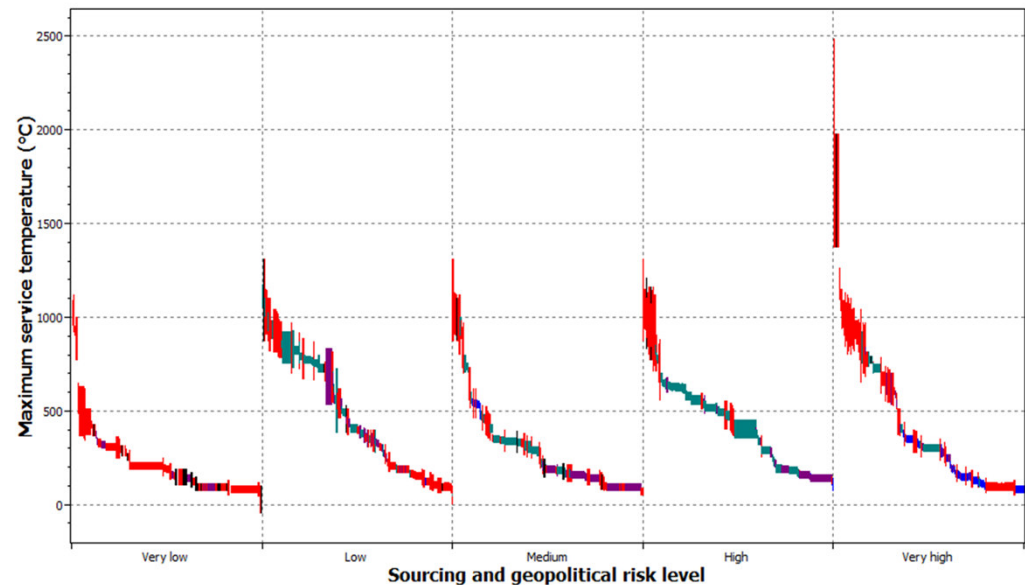


Goal:

To equip advanced engineering organisations with the data needed to identify their business and product specific risks from materials, manufacturing processes & suppliers.

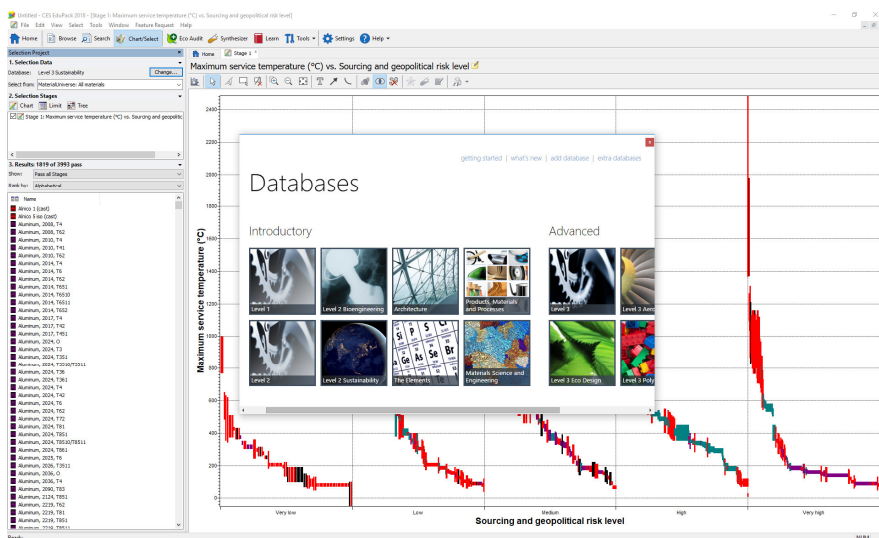
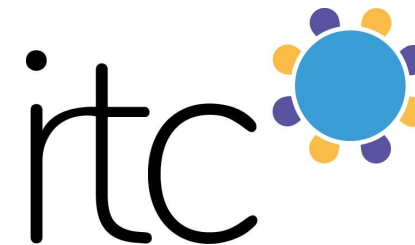
Scope:

- Evaluate materials, processes, parts, products and portfolios.
- Identify risks linked to product performance and delivery.
- Risks linked to traceable engineering materials data (reference & in-house).
- Coverage:
 - 65 abiotic elements
 - 10,500 substances
 - 4,000+ commercially available materials



Goal and Scope

As part of materials education:

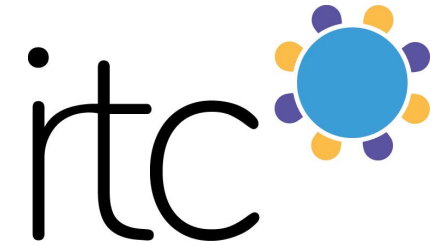


Materials selection software
Teaching resources...



Over 1,000 Universities and Colleges

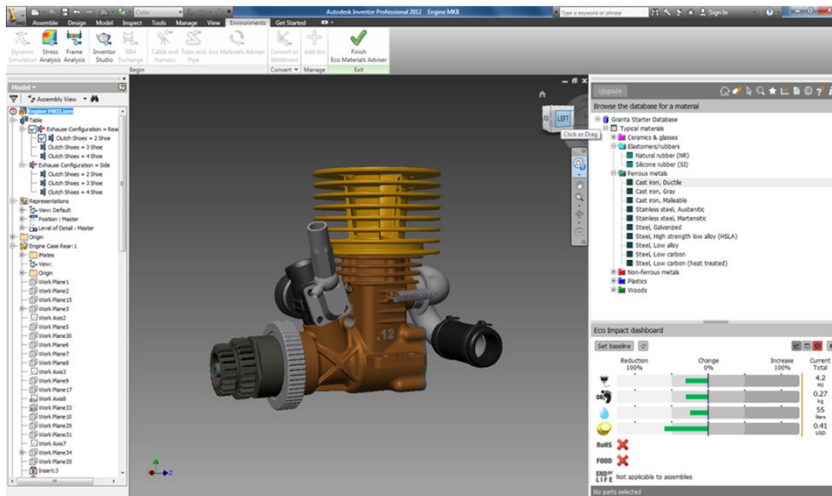
Goal and Scope



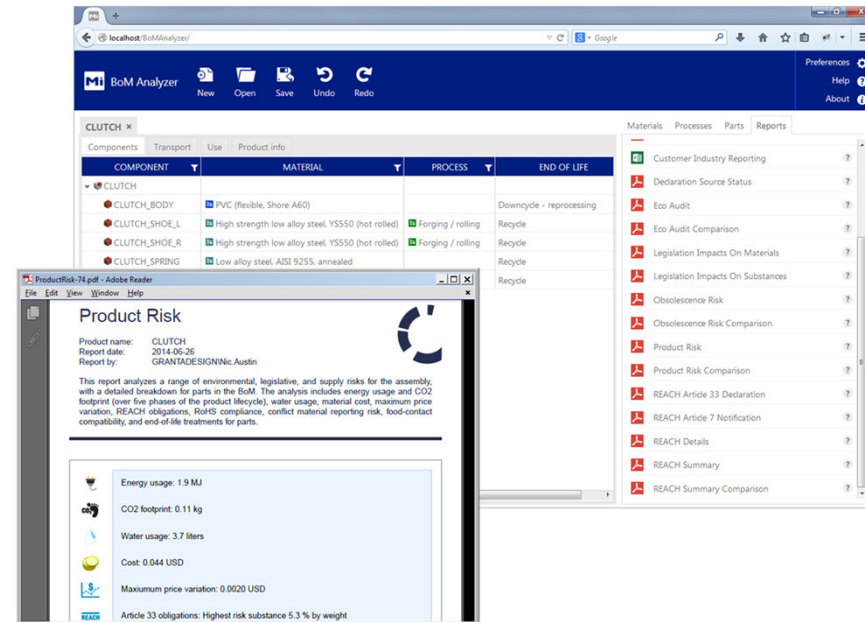
For industry:

Delivering the right data to the right person in their native environment:

- Alongside the secure, approved, access controlled engineering design data they use everyday.

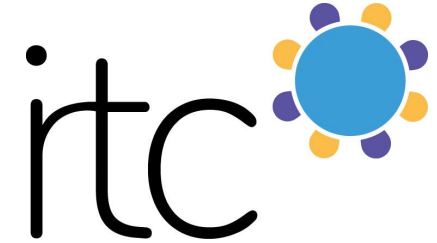


CAD & PLM integrated reporting



Web-based BoM reporting

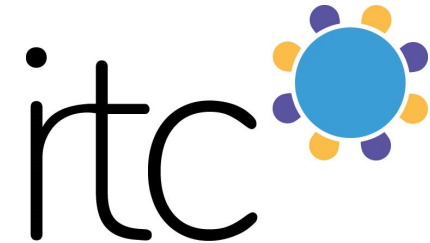
Goal and Scope



Metrics:

- *Restricted Substances (data maintained quarterly by Granta)*
 - *10,500+ substances, 125+ legislations, lists & standards*
- *Critical & Conflict Minerals – maintained annually*
 - *Monopoly of supply - HHI*
 - *Geopolitical Risk - HHI(WGI)*
 - *Environmental Country Risk - HHI(EPI)*
 - *Conflict minerals risk (Dodd Frank and EU legislation)*
 - *Price volatility*
 - *Crustal Abundance*
- *Environmental Impacts*
 - *Energy*
 - *CO₂*
 - *Water*
 - *EcolInvent*
- *Product Circularity – circularity indicators, Multiple life-cycle LCA.*

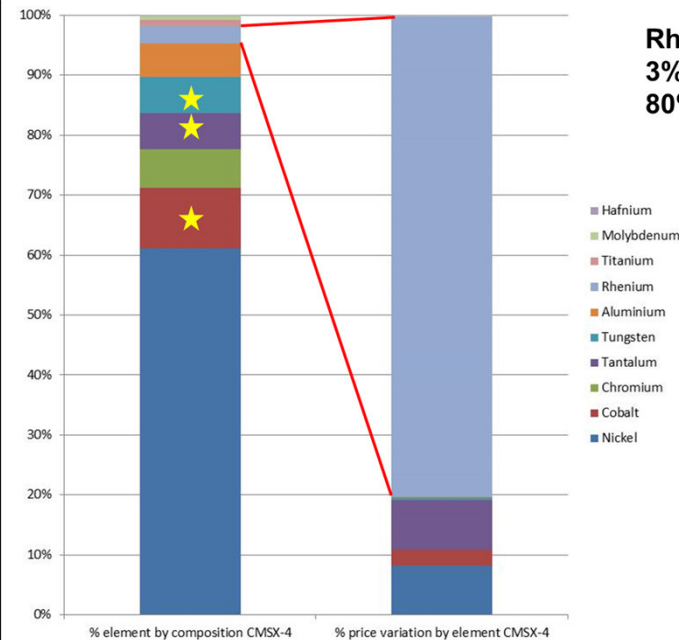
Scope explanation



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

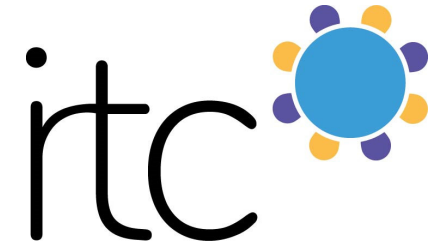


Rhenium:
3% of composition
80% of price variation

For industry, Critical materials are:

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

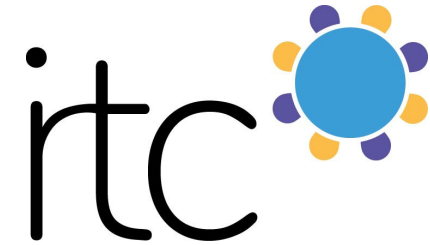
Scope explanation



Not all supply chain risks concern everyone:

- Industry want to:
 - Integrate risks into standard business processes.
 - Choose which risks to consider (and add new risks)
 - Understand the context of each risk to make appropriate decisions.
 - Decide how 'economically significant' a risk is to their business.
 - Decide how 'substitutable' a material is for their product.
- Granta's objective is to provide the tools and data needed to enable this assessment
 - An ever changing landscape.
 - Need to respond quickly.
 - Minimise and appropriately target expensive data gathering.

Factor explanation



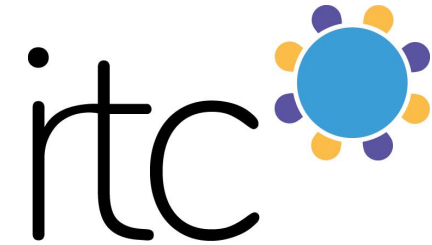
- Abundance
- Monopoly of Supply
- Geopolitical Risk
- Environmental Risk
- Price Volatility
- Conflict Minerals
- Substances legislation

Periodic

1 IA 1A	2 IIA 2A											18 VIIIA 8	19 IIIB 3B	20 IVB 4B	21 VB 5B	22 VIB 6B	23 VIIB 7B	24 VIII 8	25 VIII 8	26 VIII 8					
1 H Hydrogen 1.008	2 He Helium 4.0026											18 Ar Argon 39.948	19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.88	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.845					
3 Li Lithium 6.941	4 Be Beryllium 9.012											36 Kr Krypton 83.80	37 Rb Rubidium 84.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.94	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07					
11 Na Sodium 22.990	12 Mg Magnesium 24.305											54 Xe Xenon 131.29	55 Cs Cesium 132.905	56 Ba Barium 137.327	57-71 Lanthanide Series	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.23					
19 K Potassium 39.098	20 Ca Calcium 40.078											82 Pb Lead 207.2	83 Bi Bismuth 208.98	84 Po Polonium [209]	85 At Astatine [210]	86 Rn Radon [222]	87 Fr Francium 223.020	88 Ra Radium 226.025	89-103 Actinide Series	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [265]	
											57 La Lanthanum 138.906	58 Ce Cerium 140.115	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.24	61 Pm Promethium [145]	62 Sm Samarium 150.36	63 Eu Europium 151.966	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.50	67 Ho Holmium 164.930	68 Er Erbium 167.26	69 Tm Thulium 168.934	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967
											89 Ac Actinium 227.028	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium 237.048	94 Pu Plutonium 244.064	95 Am Americium 243.061	96 Cm Curium 247.070	97 Bk Berkelium 247.070	98 Cf Californium 251.080	99 Es Einsteinium [254]	100 Fm Fermium 257.095	101 Md Mendelevium 258.1	102 No Nobelium 259.101	103 Lr Lawrencium [262]

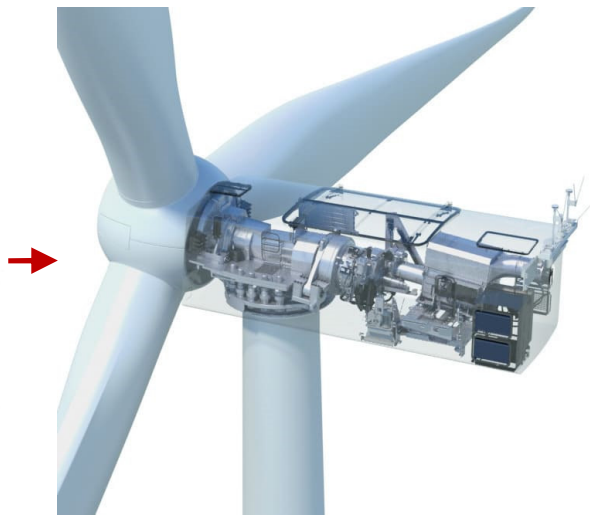


Factor explanation



Periodic Table of the Elements

1	2											10	11	12	13	14	15	16	17	18															
1A	2A											3A	4A	5A	6A	7A	8A																		
1	H	2	He																	10	Ne														
1.008		4.003																		19.998															
3	Li	4	Be											5	B	6	C	7	N	8	O	9	F	10	Ne										
6.941	6.941	9.012												10.81	12.011	14.007	15.999	18.998	20.180																
11	Na	12	Mg	13	Al	14	Si	15	P	16	S	17	Cl	18	Ar																				
22.990	24.305	26.982	27.98	26.982	28.086	28.086	28.086	30.974	30.974	32.06	32.06	35.453	35.453	39.948																					
19	K	20	Ca	21	Sc	22	Ti	23	V	24	Cr	25	Mn	26	Fe	27	Co	28	Ni	29	Cu	30	Zn	31	Ga	32	Ge	33	As	34	Se	35	Br	36	Kr
39.098	40.078	44.956	47.88	50.942	51.996	54.938	58.933	58.933	63.546	63.546	65.39	69.723	72.61	74.922	78.09	78.904	84.91	84.91	89.904	91.224	92.906	95.94	97.90	101.07	102.905	106.42	107.868	112.411	114.818	118.71	121.757	127.6	126.904	131.29	
37	Rb	38	Sr	39	Y	40	Zr	41	Nb	42	Mo	43	Tc	44	Ru	45	Rh	46	Pd	47	Ag	48	Cd	49	In	50	Sn	51	Sb	52	Te	53	I	54	Xe
85.468	87.62	88.906	91.224	92.906	95.94	98.907	101.07	102.905	106.42	107.868	112.411	114.818	118.71	121.757	127.6	126.904	131.29																		
55	Cs	56	Ba	57-71	72	Hf	73	Ta	74	W	75	Re	76	Os	77	Ir	78	Pt	79	Au	80	Hg	81	Tl	82	Pb	83	Bi	84	Po	85	At	86	Rn	
132.905	137.327	173.04	187.04	188.906	188.906	188.906	188.906	188.906	188.906	188.906	188.906	188.906	188.906	188.906	188.906	188.906	188.906	188.906	188.906	188.906	188.906	188.906	188.906	188.906	188.906	188.906	188.906	188.906	188.906	188.906	188.906	188.906	188.906	188.906	
87	Fr	88	Ra	89-103	104	Rf	105	Db	106	Sg	107	Bh	108	Hs	109	Mt	110	Ds	111	Rg	112	Cn	113	Uut	114	Fl	115	Uup	116	Lv	117	Uus	118	Uuo	
223.021	226.025	289	289	289	289	289	289	289	289	289	289	289	289	289	289	289	289	289	289	289	289	289	289	289	289	289	289	289	289	289	289	289	289	289	
Lanthanide Series		57	La	58	Ce	59	Pr	60	Nd	61	Pm	62	Sm	63	Eu	64	Gd	65	Tb	66	Dy	67	Ho	68	Er	69	Tm	70	Yb	71	Lu				
Actinide Series		89	Ac	90	Th	91	Pa	92	U	93	Np	94	Pu	95	Am	96	Cm	97	Bk	98	Cf	99	Es	100	Fm	101	Md	102	No	103	Lr				
		227.028	232.038	231.036	238.029	237.048	244.044	243.061	244.064	243.061	244.064	243.061	244.064	243.061	244.064	243.061	244.064	243.061	244.064	243.061	244.064	243.061	244.064	243.061	244.064	243.061	244.064	243.061	244.064	243.061	244.064	243.061	244.064		



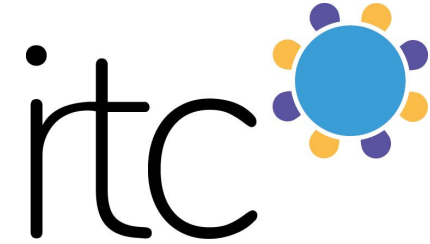
The supply of the element may be the cause of a risk.

The real business risk is a Product Risk, i.e. an inability to deliver a product:

- At cost
- At volume
- In line with legislation or customer expectations.

This is about more than individual elements.

Factor explanation



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	

The screenshot shows the Autodesk Inventor Professional 2021 interface. A 3D model of a clutch assembly is displayed in the center. On the right side, there is an 'Eco Impact dashboard' window showing various metrics and charts. The dashboard includes a 'Set baseline' section with 'Change' and 'Process' bars, and a 'Risk' section with 'FOOD' and 'REACH' indicators.

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

The screenshot shows the BoM Analyzer software interface. The main window displays a 'Product Risk' report for the 'CLUTCH' component. The report includes the following information:

- Product name: CLUTCH
- Report date: 2014-06-26
- Report by: GRANITDESIGNNIC-Austin

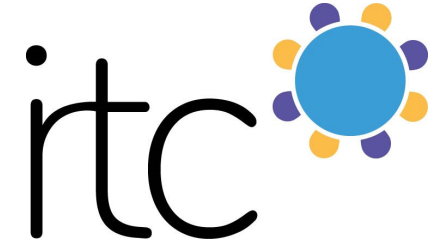
The report text states: "This report analyzes a range of environmental, legislative, and supply risks for the assembly, with a detailed breakdown for parts in the BOM. The analysis includes energy usage and CO2 footprint (over five phases of the product lifecycle), water usage, material cost, maximum price variation, REACH obligations, RoHS compliance, conflict material reporting risk, food-contact compatibility, and end-of-life treatments for parts."

Key metrics shown in the report include:

- Energy usage: 1.9 MJ
- CO2 footprint: 0.11 kg
- Water usage: 3.7 liters
- Cost: 0.044 USD
- Maximum price variation: 0.0020 USD
- Article 33 obligations: Highest risk substance 5.3 % by weight

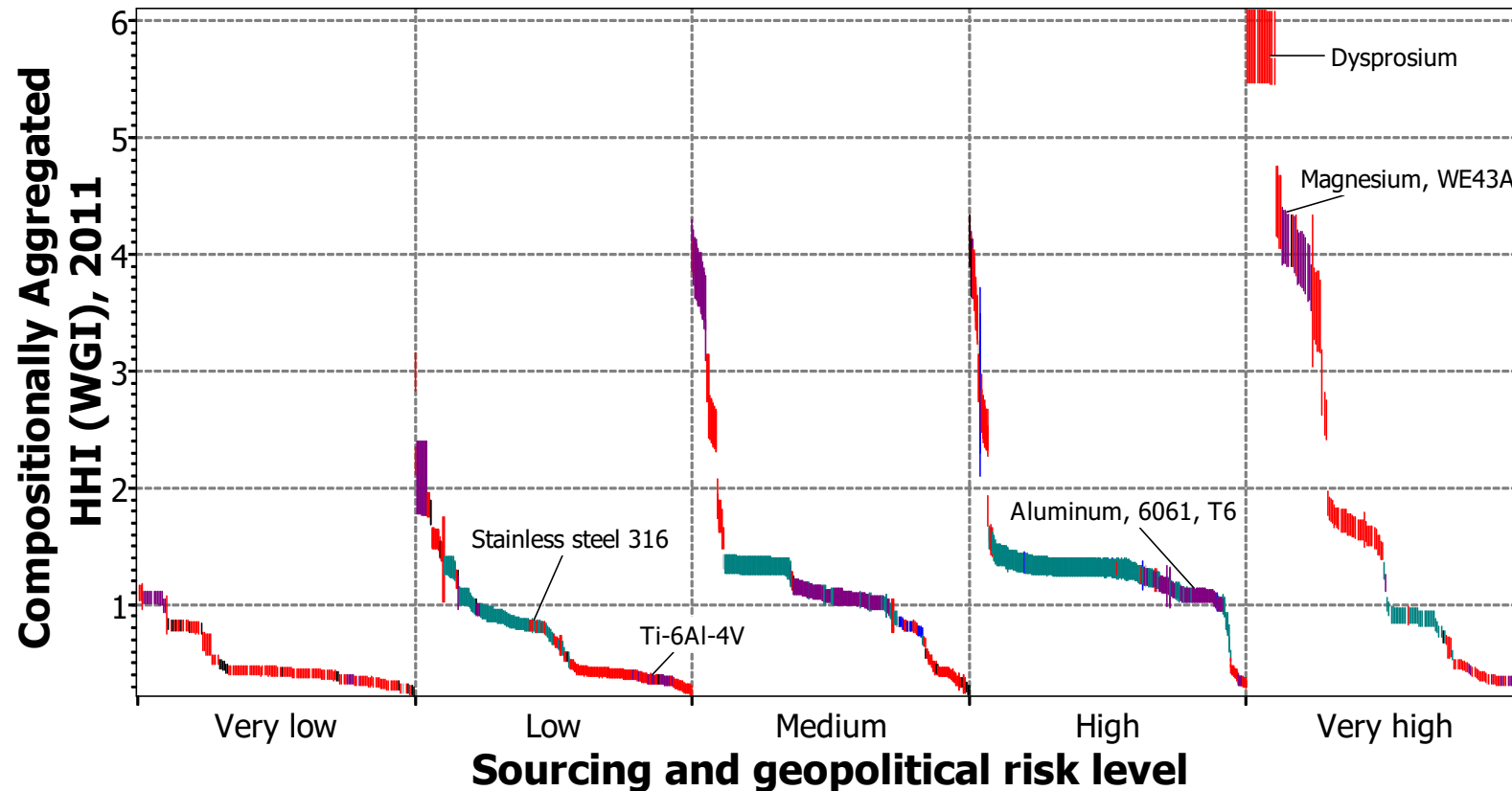
The interface also shows a table of components with their materials and end-of-life processes, and a sidebar with various reporting options like 'Declaration Source Status', 'Eco Audit', and 'REACH Article 33 Declaration'.

Aggregation



- As a general rule Granta doesn't aggregate risks.
(we do however support customer specific aggregation)
- We find aggregation often masks the cause of the risk → Inhibits development of a suitable response.
- An exception exists for some material or product level reporting:
 - Where we need to consider the aggregate risk arising from multiple elements.
 - This is still optional.

New method: Considers overall risk of composition
Aggregating sourcing of each element

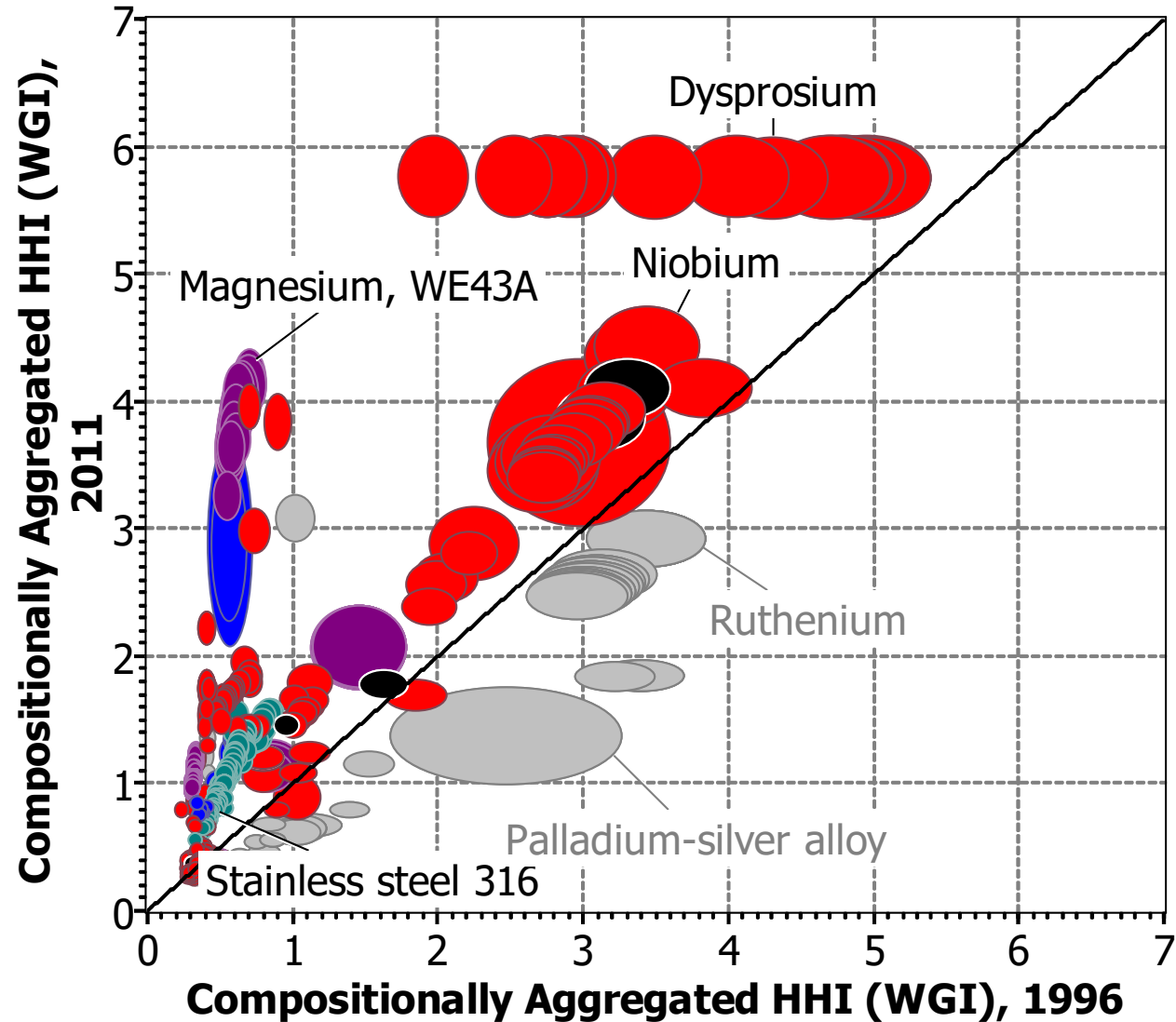


Old method: Material adopts highest risk of all elements in composition

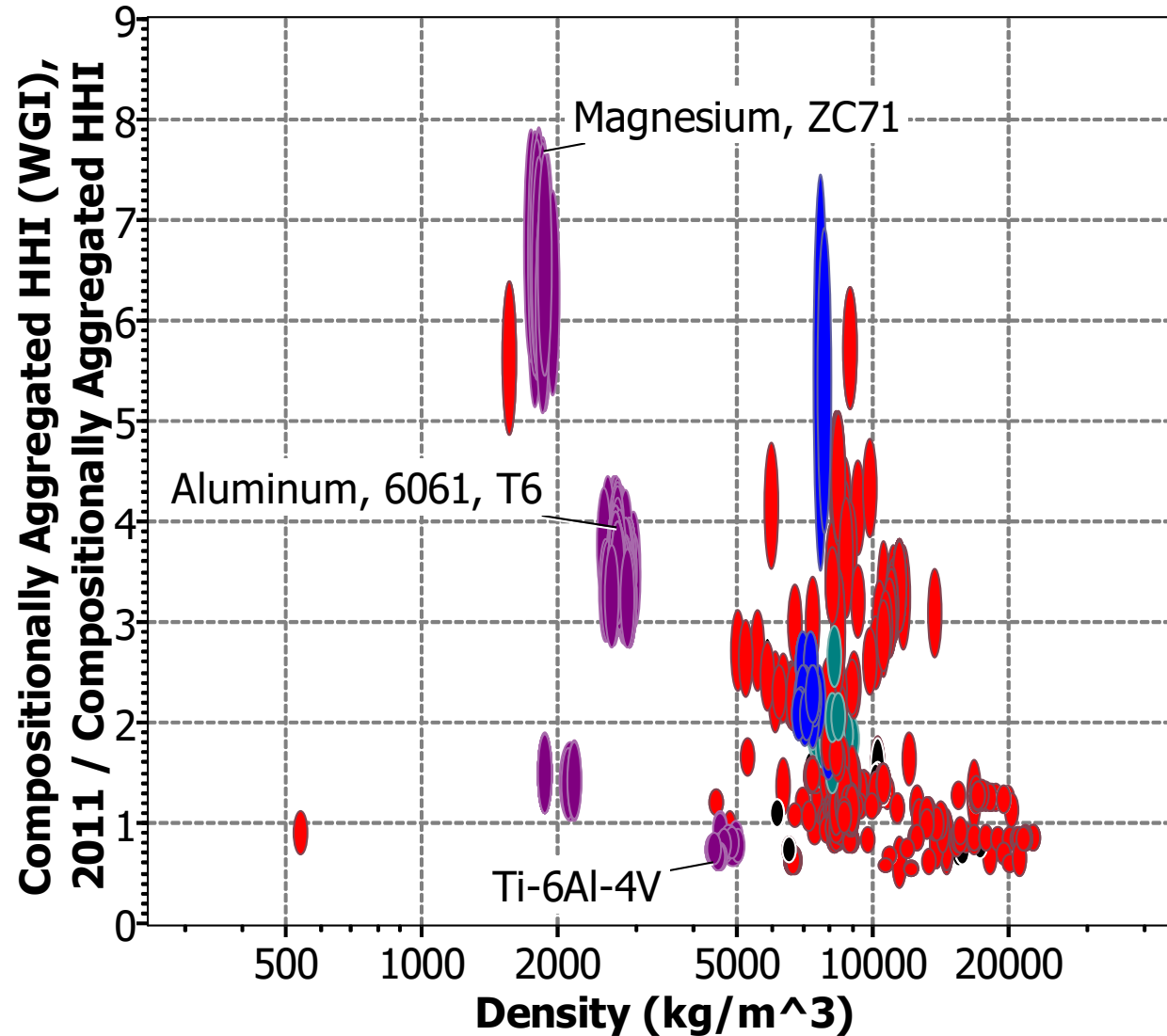
Need to differentiate between:

1. High concentration, High Risk materials (generally important)
2. Low concentration, High risk materials (more important to high volume uses)

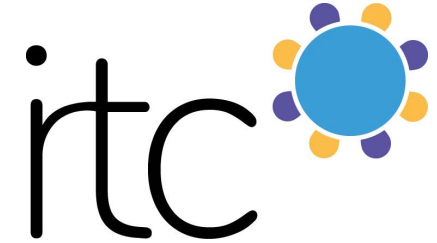
This allows us to do some unique analyses



This allows us to do some unique analyses



Unique features



- Our data is specifically linked to the material properties.
 - These are what is at risk – the product function fulfilled by the material.
 - Our data is reputable and traceable (reference and customer data).
 - GRANTA MI manages the pedigree of materials data more generally within the business.
- Risks are material, product, business specific.
 - Regulatory risks – e.g. REACH, Conflict Minerals
 - Supply and reputational risks – e.g. geopolitical, environmental, price, conflict
 - Environmental risks – energy, CO2, water, cost.
- We don't pre-determine what is critical to the user.
- Assessments are quick to conduct – push of a button!
 - Means we can rapidly repeat assessments once the risks have changed.

Results and implications



- General lists of critical materials are not useful to business.
 - Need specific clarity over the materials that they use directly.
- Feedback from users has been very positive.
 - Solution was developed in direct collaboration with industry users from EMIT.



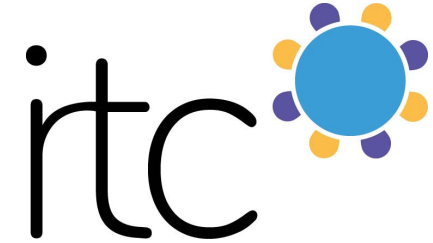
Members

Airbus Helicopters
Boeing
Bombardier
Emerson Electric
GKN Aerospace
Honeywell
NASA
NPL
Pratt & Whitney
Rolls-Royce
Sandia National Labs
US Army Research Labs

<https://www.grantadesign.com/emit/>

- Currently in use by many and investigating additional risk factors.

Results and implications

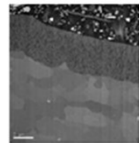


REACHing out for new materials

With hexavalent chromium recently placed on the REACH list of restricted substances, the aerospace industry is searching for replacement materials for surface treatments.

Chris Duggan, Head of Surface Engineering at Solvay, UK, explains how the REACH-CR HESA project is addressing the issue.

The aerospace industry is heavily reliant on surface treatments containing hexavalent chromium to prevent corrosion and wear on products that have a long life in service. In fact, hexavalent chromium compounds such as chromate trioxide (chromic acid) and chromic anhydride are used in various chemical processes. Hexavalent coatings include chromate and anodizing (CDA) have a number of advantages. Hexavalent coatings are used in various chemical processes. Hexavalent coatings include chromate and anodizing (CDA) have a number of advantages. Hexavalent coatings are used in various chemical processes. Hexavalent coatings include chromate and anodizing (CDA) have a number of advantages.



Hexavalent chromium compounds are used in various chemical processes. Hexavalent coatings include chromate and anodizing (CDA) have a number of advantages.

Hexavalent coatings are used in various chemical processes. Hexavalent coatings include chromate and anodizing (CDA) have a number of advantages. Hexavalent coatings are used in various chemical processes. Hexavalent coatings include chromate and anodizing (CDA) have a number of advantages.

- Consortium of 17 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
 - Identified candidate solutions known to be subject to risk
 - Reduction in long-term risk.
 - Long-term traceability over all data.

Limitations



- Commercially licenced tool and data.
 - We are pretty flexible and open to collaboration though.

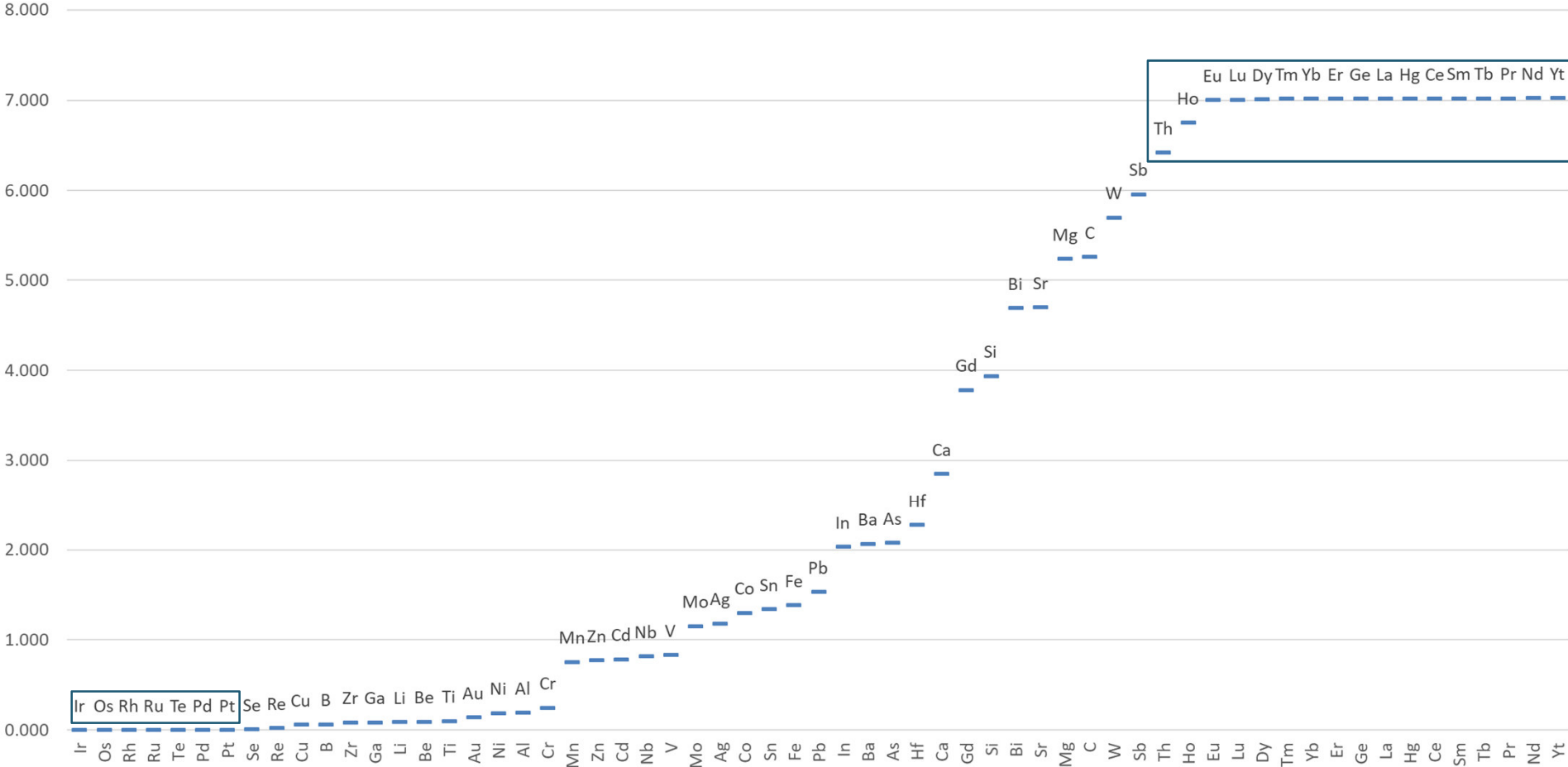
Outlook



- Very positive.
- Currently investigating:
 - Climate risks e.g. Natural disasters, severe weather, coastal disruption.
 - Social risks e.g. Child labour:

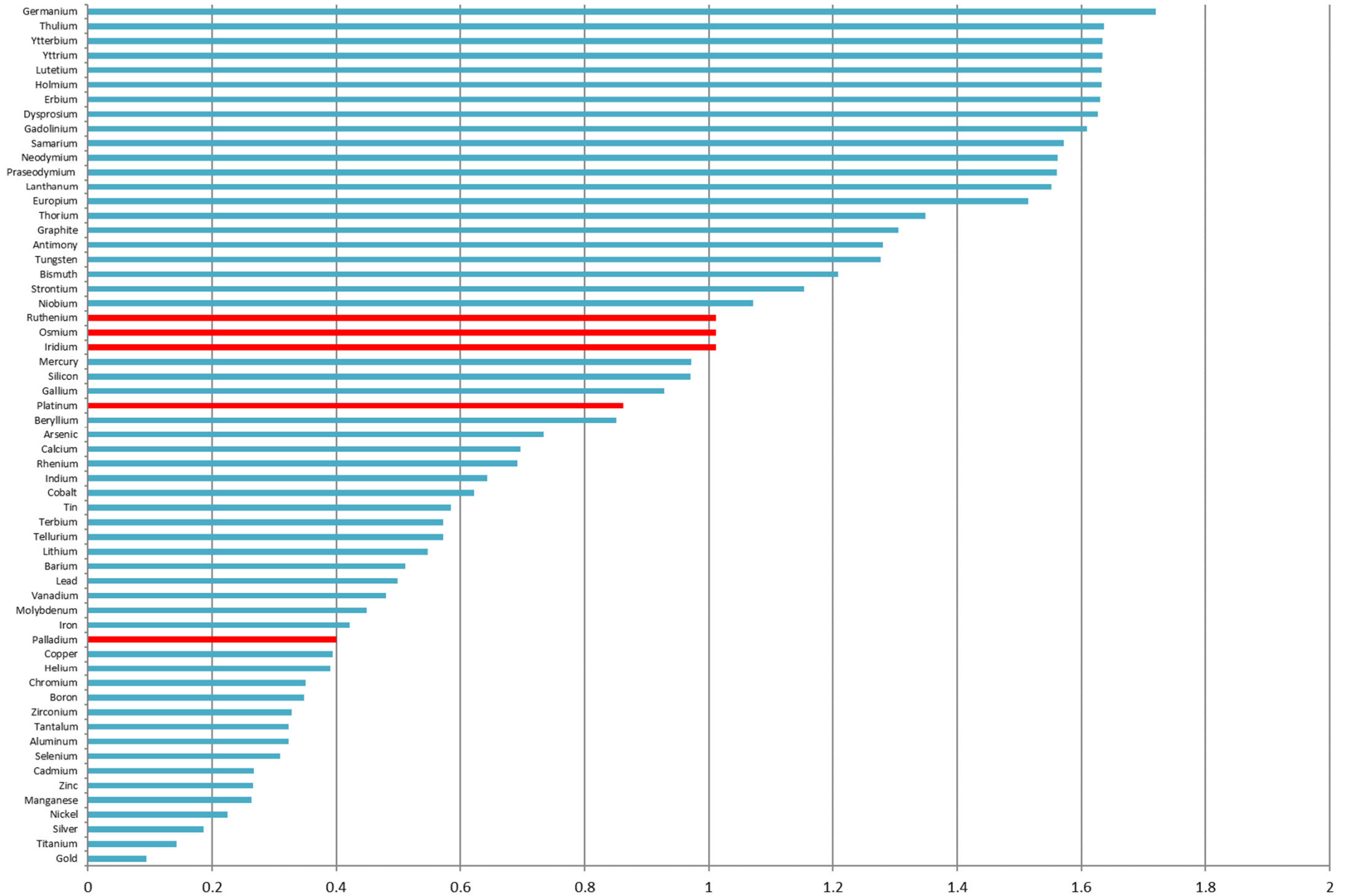
Risk Metric Calculations

Child Labour Index



Draft – requires further work

World Risk Index - Initial Assessment (2011 Data)



Draft – requires further work