EPSRC Centre for
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Technical Seminar Series

Eco-Factory Grand Challenge

Optimisation, Rationalisation and Resilience Tools

16:00-17:00 5 March 2015

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Technical webinar series – schedule

5 MARCH 2015

We will record this webinar and issue the recording afterwards

Slides will also be made available

Please use chat to raise questions throughout the presentations

Questions after this presentation finishes? Please contact

Dr James Colwill <j.a.colwill@lboro.ac.uk>

- **Today:** Eco-Factory Grand Challenge: Optimisation, Rationalisation and Resilience Tools
- **Next time:** 26 March & 30 April
- Future months: much more to follow!!
- … and it could be you…
- Typically first Thursday of the month

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Technical webinar series – the aims

5 MARCH 2015

- Sharing **research** results and **industrial** practice for Centre members
- **Connecting people** within the Centre as outside the Centre
- Providing **feedback**, comments, suggestions, refinement, etc to those presenting

If you have interesting content to share from research and development, good practice, valuable results in practice, etc. then perhaps you should be scheduled in the series.

Contact Sharon Mey cis-admin@ eng.cam.ac.uk

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Vision & aims

By 2016:

20 Grand Challenge Projects

Engage with 200+ manufacturers

Start over 88 PhDs

Build over 50 Quick Guides

Influence policy in UK, EU and BRICS

Our shared Challenge – by 2050:

- To quadruple manufacturing output by value
- To emit 80% less GHG
- To halve resource use
- In an equitable & resilient manner

The Centre will deliver:

- Knowledge
- Tools & methods
- Leaders
- Policy support & influence
- Visions for a successful future

The EPSRC Centre for Innovative Manufacturing in Industrial Sustainability will support the development of a sustainable UK industrial system through the provision of knowledge, leaders, tools & methods and policy support, all grounded in practice. We will be global in outlook, open & pro-active in working with others, and transparent about our successes and failures.

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Current Research Themes

Eco-efficiency	How to make current products in a low-carbon, resource efficient manner.
Eco-technology & Eco-Factory	How to transform our factories and products.
Sustainable Business Models	
Sustainable industrial Systems	Explore how the entire industrial system might change

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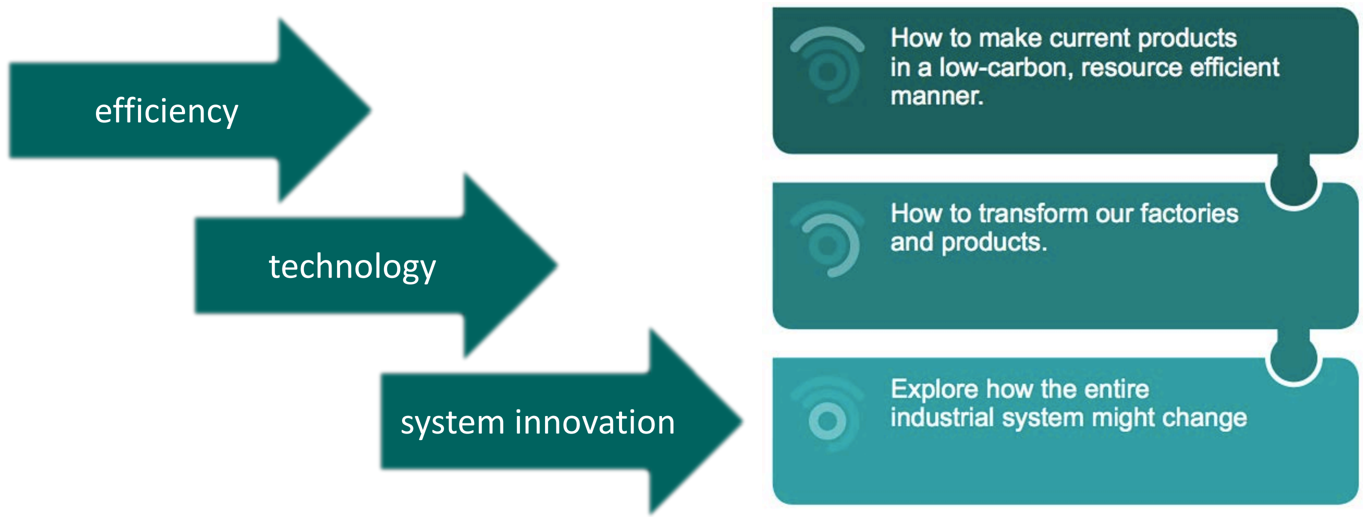
Research Themes and Activities

THREE MAIN THEMES

The Challenge

"One day, this will all be your fault."



4 Universities
50 Researchers
100+ Companies
13 New tools
16 Guides

6 Grand Challenge Projects – MultiYear - PDRA & PhD Teams
27 Explore Projects – 3-6 Months – PDRA Teams
7 Policy Research – 3-12 Months – Snr Academic & PDRAs
67 Cohort Development – Continuous – Self Organizing

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Eco-Efficiency Grand Challenge: Resource Efficiency in the Factory

5 MARCH 2015

16.00 **Introduction** (James)

16.10 **Overview of Grand Challenge** (James)

16.20 **Material Flow Modelling** (Oliver)

16.35 **Resilient Manufacturing** (Liam)

16.50 **Wrap up** (James)

17.00 **Close**

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Overview of the
Eco-Factory Grand Challenge
Resource Efficiency Manufacturing

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What is resource-efficiency?

DEFINITION – THE CONCEPT

DO

MORE

WITH

L E S S

Resource Efficient Manufacturing: REM

Aims and Objectives

- Reduce resource consumption whilst increasing useful output
- To develop novel technologies, methodologies and tools to support radical improvements in REM.

Why is the research needed?

- Present trajectory of resource consumption is unsustainable
- Current approaches to supporting resource efficiency largely through incremental improvements.
- Manufacturers require assistance with decision making when using strategies for improving resource efficiency.

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Project Scope

Manufacturing resources: Materials, Energy & Water

SMART Energy and Water modelling tools have been developed

Current focus is on **Materials Efficiency**

Integration of Materials, Water and Energy assessment:

- 'SMART Resource Efficiency Dashboard'

Long term Centre objective

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Material Efficient Manufacturing

Material Flow Modelling and Optimisation

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Material Efficient Manufacturing

- Provide same product service with less material production and processing
  - reduce consumption
  - improve environmental performance
- Investigate ways to support improvement:
  - Define performance
  - Material flow modelling
  - Assist implementation of improvement strategies and tactics

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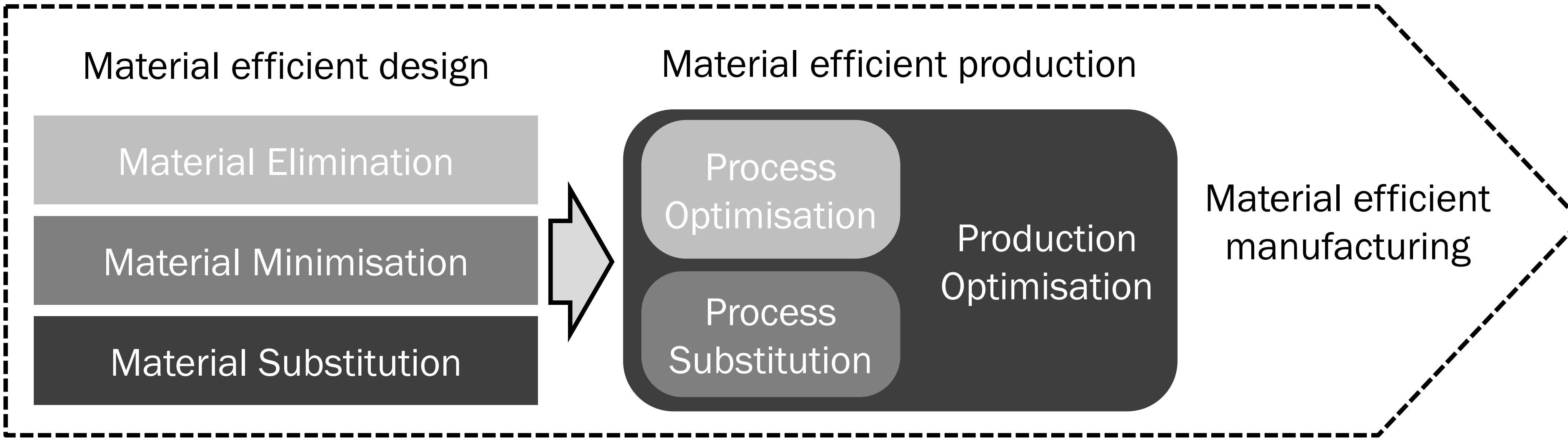
Material Efficiency

STRATEGIES IN MANUFACTURING

- What can manufacturers do to improve material efficiency?

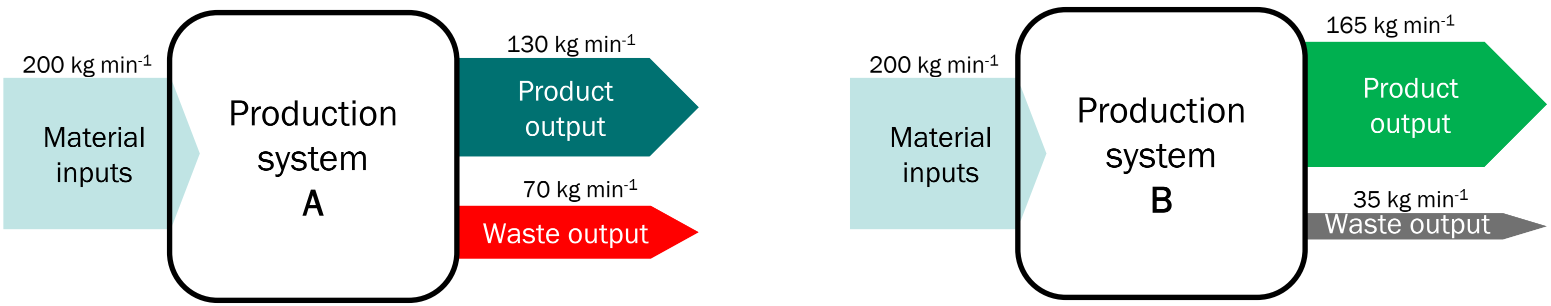


- Product and production design broadly defines material flow
- Strategies may influence flow in various ways
  - Model strategies - aid decision making

Material flow improvements

MATERIAL EFFICIENT PRODUCTION

- process time and scheduling, changeovers, cleaning
- impact of material losses
- material contamination and partitioning
- resource interactions (water, energy)
- **overall yield**



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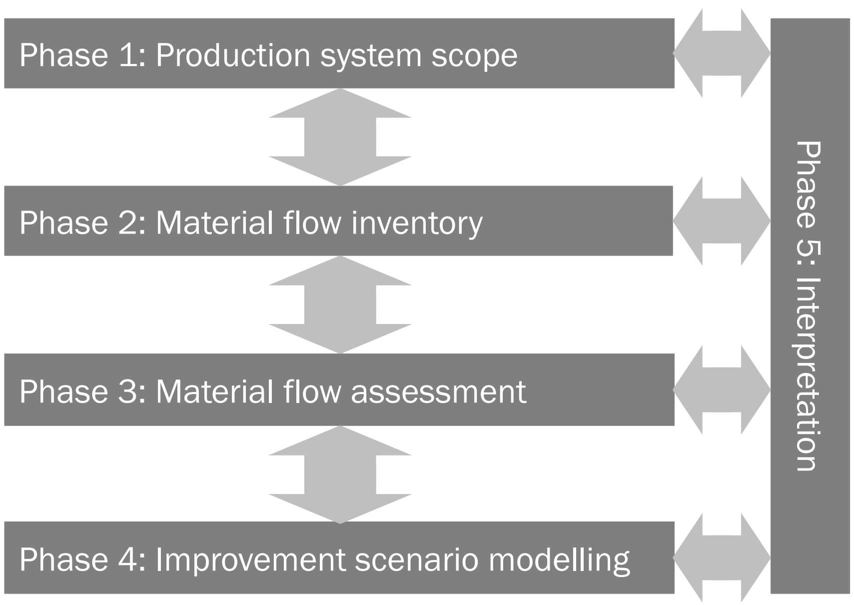
Material Flow Assessment:

Model flow, define and improve performance

- Material efficiency intrinsically linked to material flow in factory
- Material flow assessment framework



- Define and model material flow
  - quantitative
  - qualitative
- Assessment of efficiency and impacts
  - descriptive
- Model strategies
  - dynamic and simulation based modelling tools

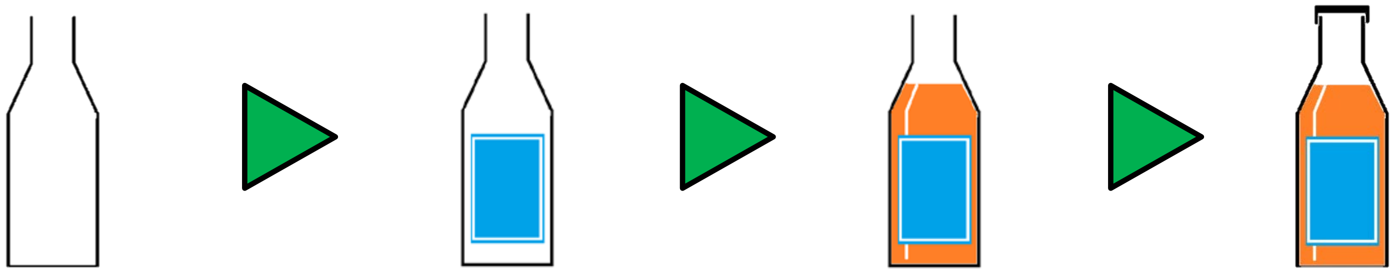
Improvement scenario modelling

CASE STUDY: PROCESS SEQUENCING

Material flow assessment

- Labelling – yield loss hotspot
- Individual process efficiency limit reached
- What options can give further improvement?

Improvement scenario: production design – alternative process sequence

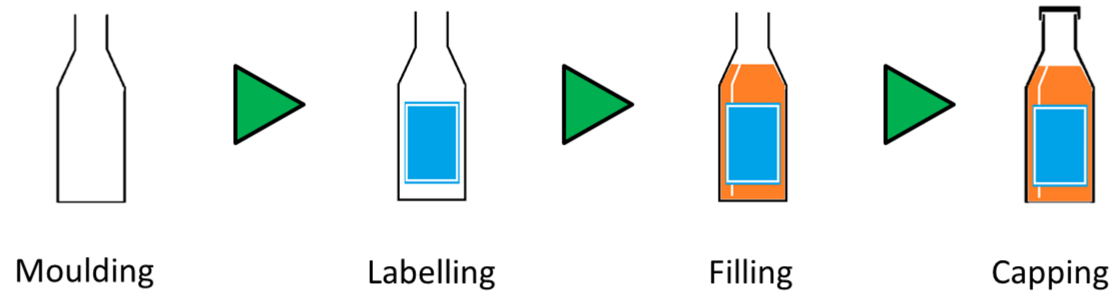


Moulding Labelling Filling Capping

Can changing the configuration improve material efficiency?

Improvement scenario modelling

CASE STUDY: PROCESS SEQUENCING



- Alternative configuration
  - improve overall yield
    - material mass
  - reduce impact of material losses
    - lost materials have greater potential for reuse or rework
- Evaluate for feasibility and confirm benefit

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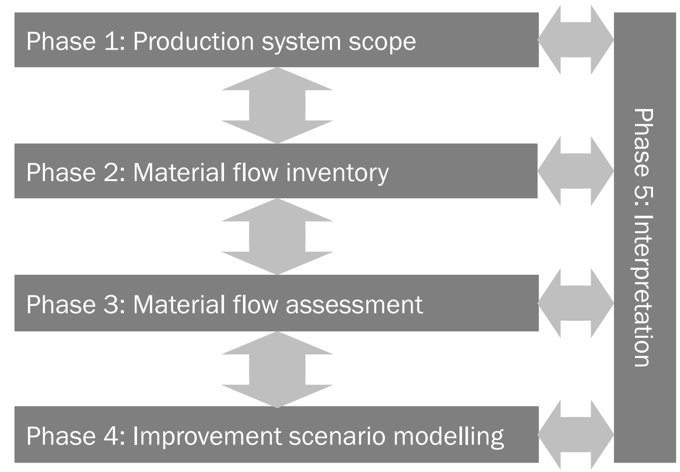
Improvement scenario modelling

CASE STUDY: PRODUCT SEQUENCING



- Material flow assessment :
  - Multiple products (>1000)
  - multiple materials (>1000)
  - Few production lines (2)
    - 2 processes; mixing and packing
  - Low yield loss
  - High potential resource consumption
    - depending on product requirements and sequence of production

- Optimise product sequence:
  - material flow optimised for minimum resource consumption
    - time (energy overheads etc.), water and cleaning materials

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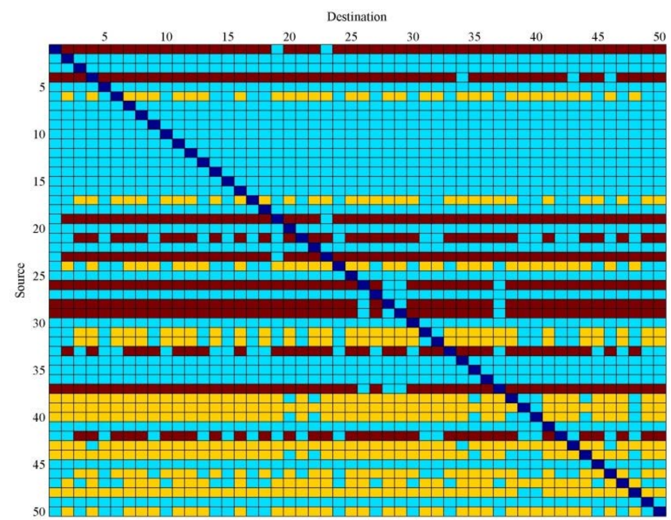
Improvement scenario modelling

CASE STUDY: PRODUCT SEQUENCING

- Multiple products (>1000)
- Some contain potentially cross contaminating materials (PCCM)
  - qualitative material properties - 8 categories of PCCM
- Product changeover requirements determined by their PCCM content
  - 3 levels of cleaning intensity, with increasing resource consumption
  - normal, medium intensity and high intensity clean

  - e.g. 50 products: changeover matrix
    - N/A,
    - NC,
    - IC,
    - WC

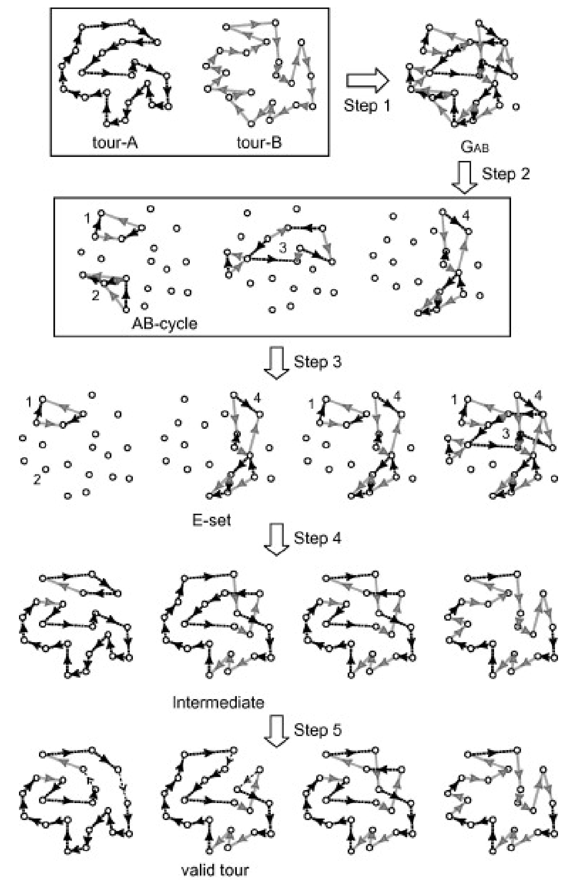


Improvement scenario modelling

CASE STUDY: PRODUCT SEQUENCING

- Sequencing of products:
  - no alteration to product or process design
  - optimise material flow - temporal
  - minimise total intensity of cleaning required

- Decision support tool
  - Utilising genetic algorithm to minimise resource consumption (‘changeover cost’)
  - Analogous to asymmetric travelling salesman problem (ATSP)
    - nodes = products,
    - distance = resources consumed
  - Source destination matrix utilised – quantification of changeover resource consumption



Yuichi Nagata, David Soler, A new genetic algorithm for the asymmetric traveling salesman problem, Expert Systems with Applications, Volume 39, Issue 10, August 2012, Pages 8947-8953

Improvement scenario modelling

CASE STUDY: PRODUCT SEQUENCING

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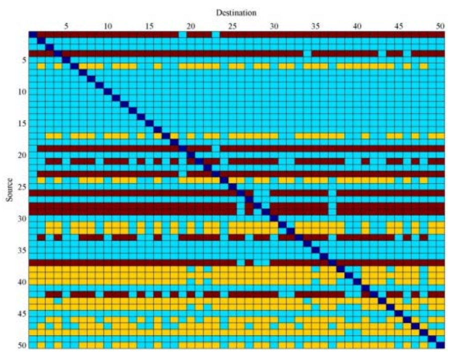
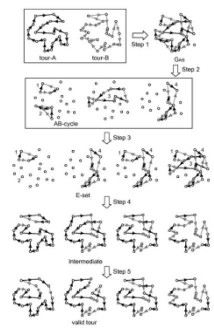
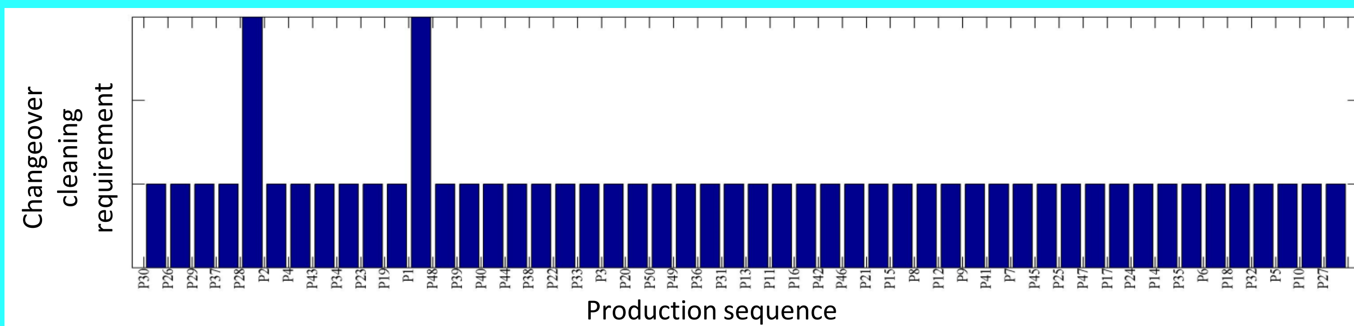




- Optimum sequence provided:
  - Improve process time, changeovers, cleaning
  - control resource interactions (water, energy) with minimised resource consumption



Improvement scenario modelling

CASE STUDY: PRODUCT SEQUENCING

- Next step:
- Rationalisation – individual product impacts
  - which products have greater tendency towards higher resource consumption?
  - what can we do about these?
    - produce for greater stock levels?
    - use alternative production process?
    - segregate line?

reduce potential for material contamination and improve partitioning

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Resilient Manufacturing Supply Chains

Critical Materials and Rare Earths

Liam Gardner

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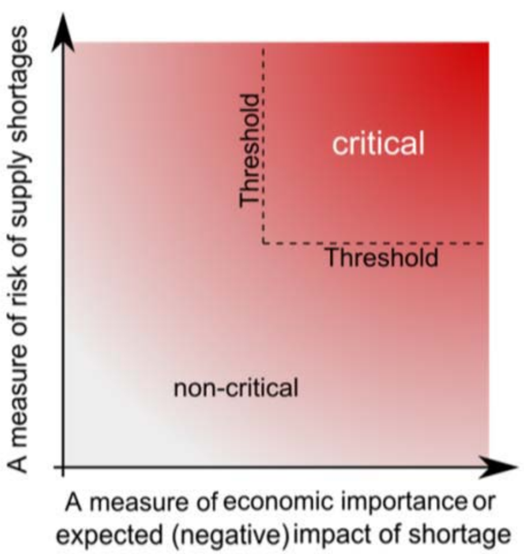
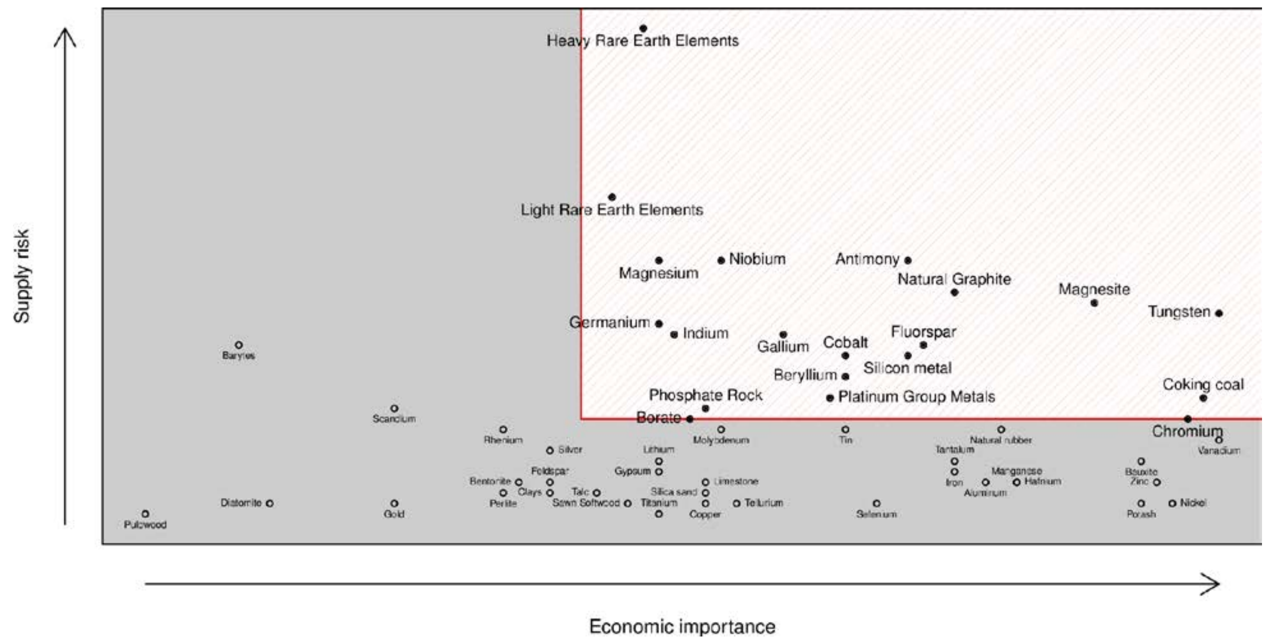
Critical Materials and Resilience

BACKGROUND

- “Critical Materials” as defined by EU Report 2014:
  - High overall economic importance
  - High supply risk





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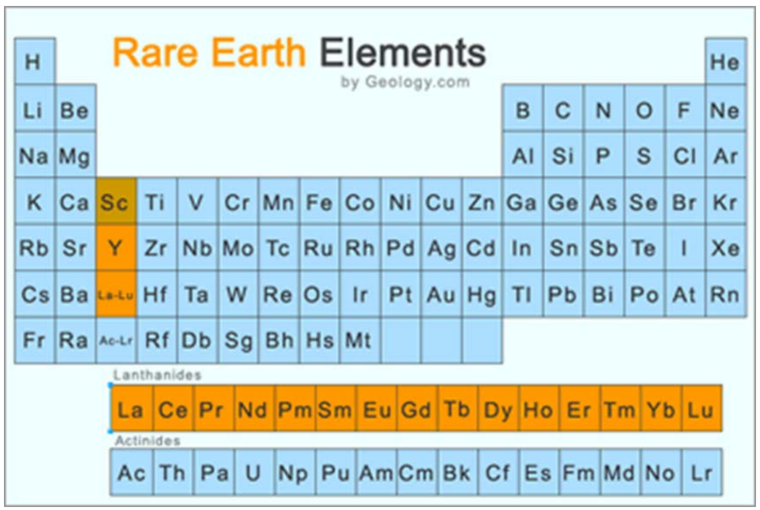
Rare Earth Elements (REE)

BACKGROUND

- 17 elements: Scandium (Sc), Yttrium (Y) & 15 Lanthanides
- Unique Chemical and Physical Properties
- “Vitamins” to Boost Performance
- Increasingly Wide Range of Modern & Clean Technologies



REE	Examples of Use
Cerium	Catalytic Converters, Oil Refining
Lanthanum	Lenses, Lighting, Oil Refining
Praseodymium	Specialist Metallurgy/Glass
Gadolinium	X-Ray, MRI, TVs
Neodymium	Magnets – Speakers/Hard Drives/ Wind Turbines/Hybrid Vehicles

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Rare Earth Elements (REE)

REE PRIMARY SUPPLY ISSUES

- Concentration main factor in determining economic viability for extraction
- Currently limited to very few sources
- Geopolitics = key factor

- High Corporate Concentration
- High Country Concentration– China up to 98%
- Industrial development strategies:
- Value-chain consolidation
- Subsidies
- Export Quotas
- Taxes
- Loss of expertise

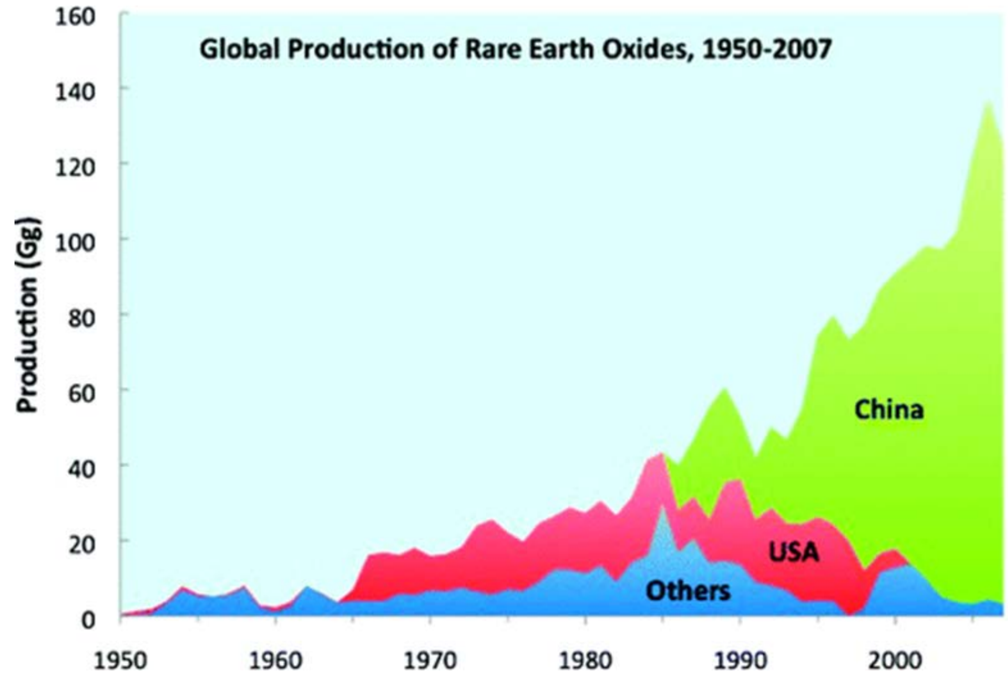

Figure showing Global Production of Rare Earth Oxides.
Source: U.S. Geological Survey, 2010

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Rare Earth Elements (REE)

ENVIRONMENTAL ISSUES

- High Consumption of: Water/Energy/Chemicals
- High Production of: Contaminated Waste Water/Heavy Metals/Toxic Chemicals/Radioactive Contaminants (Uranium, Thorium)
- Ecosystem Impacts – Opencast, Fragmentation, Tailings and Waste
- Many Pollution Incidents Reported for Soil, Surface and Ground Water

Ranking of economically important raw materials according to their environmental country risk (National Research Council 2008, European Commission 2010, Wäger et al. 2010)

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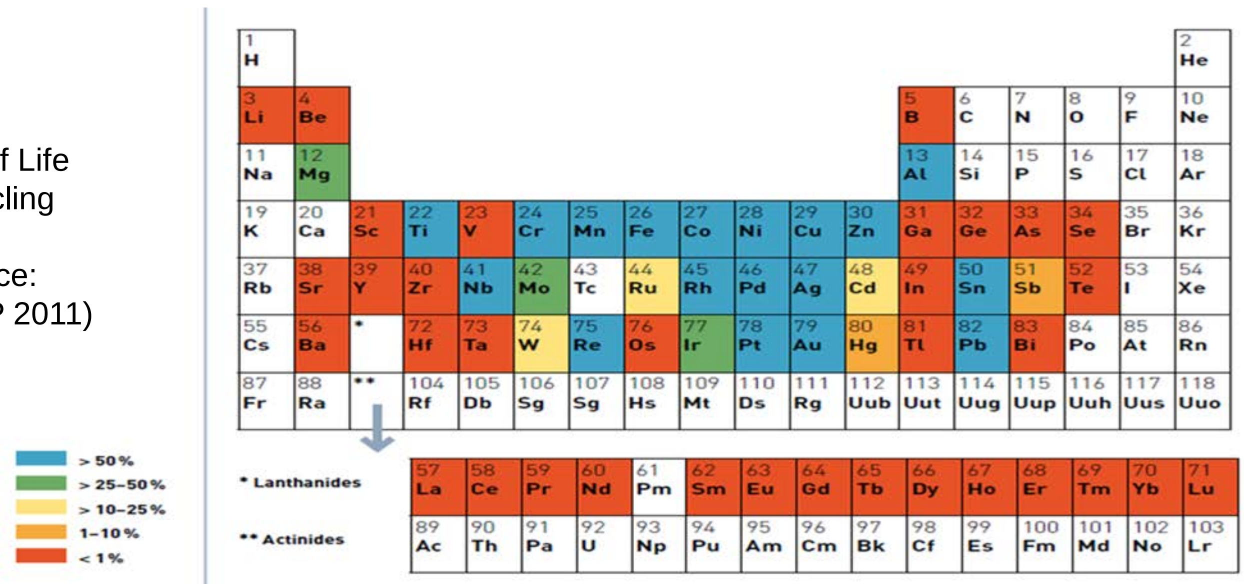
Rare Earth Elements

SECONDARY PRODUCTION

- Recovery and Recycling Rates Extremely Low <1% EoL
- Expensive & Difficult
- Small Quantities, Compounds & Mixtures → Dissipative Losses
- Permanent Magnets, Lamp Phosphors, Batteries
- Good Incentives to Increase (↓ Impacts ↑ Supply)

End of Life Recycling Rates (Source: UNEP 2011)



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Rare Earth Elements

INCREASING DEMAND

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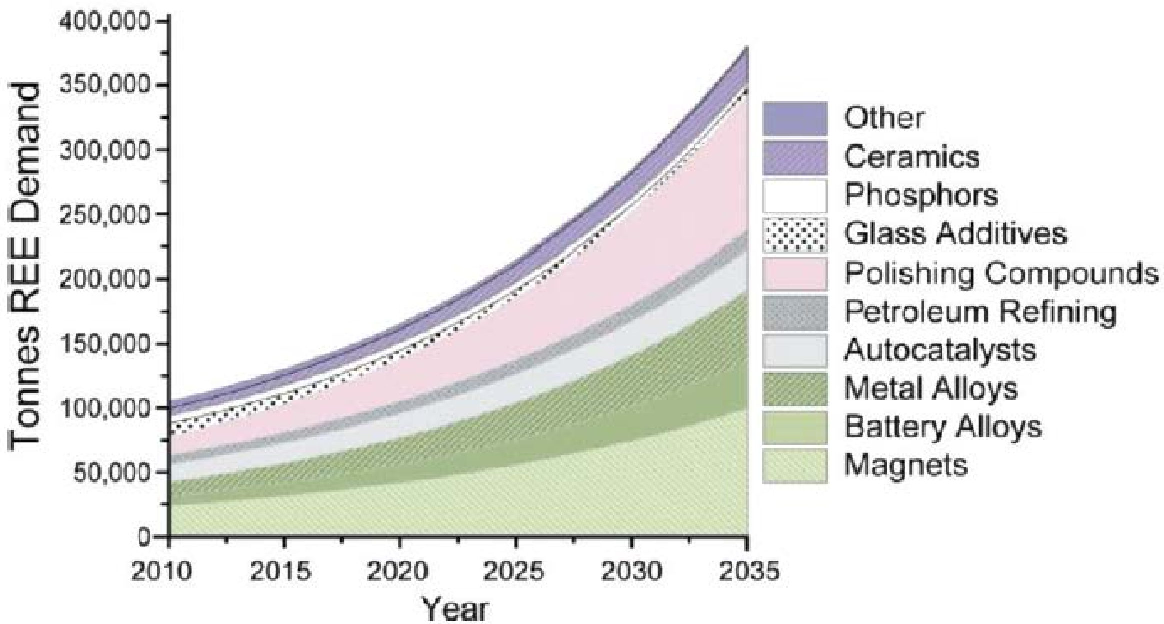
Demand increasing
Increased use in digital & clean technologies
Increased volume of REE products
Increased demand from developing economies

Figure showing estimated REE demand from market sectors.
Source: Alonso et al. 2012

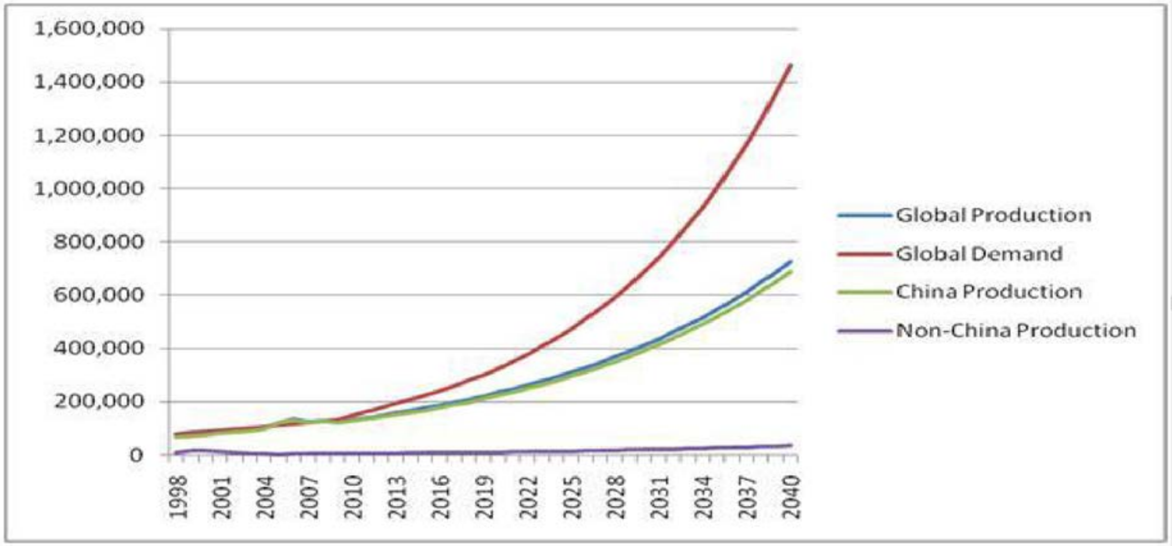


Rare Earth Elements

HIGH SUPPLY RISK + HIGH ECONOMIC IMPORTANCE = CRITICAL MATERIAL

- Extraction (Identification/Planning/Facilitation etc.)
  = Long Temporal Scales (8-10 Yr. in EU)
- Inelastic Supply to a Dynamic Demand

Graph illustrating actual and projected (from 2008 onwards) REE global production and demand including Chinese and non-Chinese production (Source: EURARE 2013)



- How can we increase business resilience to critical materials?

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Manufacturing Supply Chain Resilience

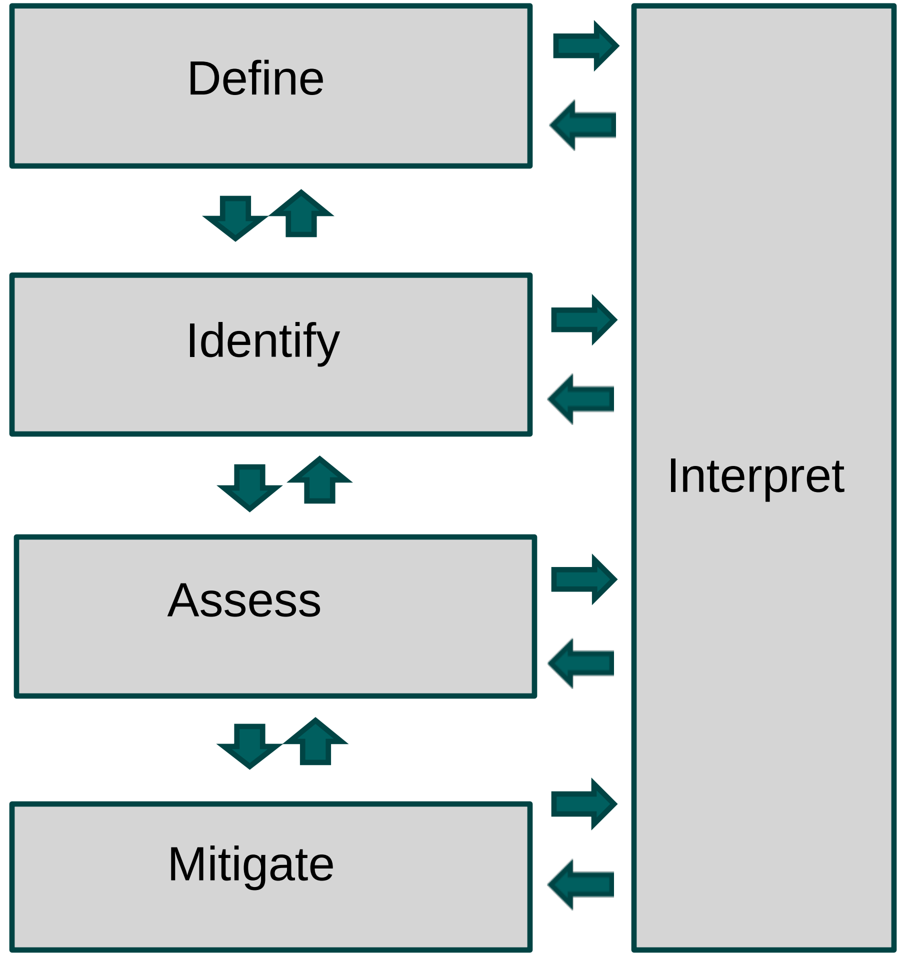
FRAMEWORK DEVELOPMENT

- Framework would be applicable to all 'critical' materials
- Many materials critical to a companies manufacturing are visible and risk is already managed
- 'Critical' materials such as rare earth elements are often hidden – used in small quantities and not purchased directly
- To manage risk one must identify exposure and quantify risk
  - Direct or Indirect impact
  - Immediate or Distant
  - Upstream or Downstream
  - Significant or Insignificant
- Then one can develop an optimal risk mitigation strategy

Manufacturing Supply Chain Resilience

FRAMEWORK STAGES FOR CRITICAL MATERIALS

- Define study
  - Interpretation
- Identify risk
  - Interpretation
- Assess risk
  - Interpretation
- Select mitigation strategy/strategies
  - Interpretation
- This is an iterative and ongoing process



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Business Decision-Support Tool

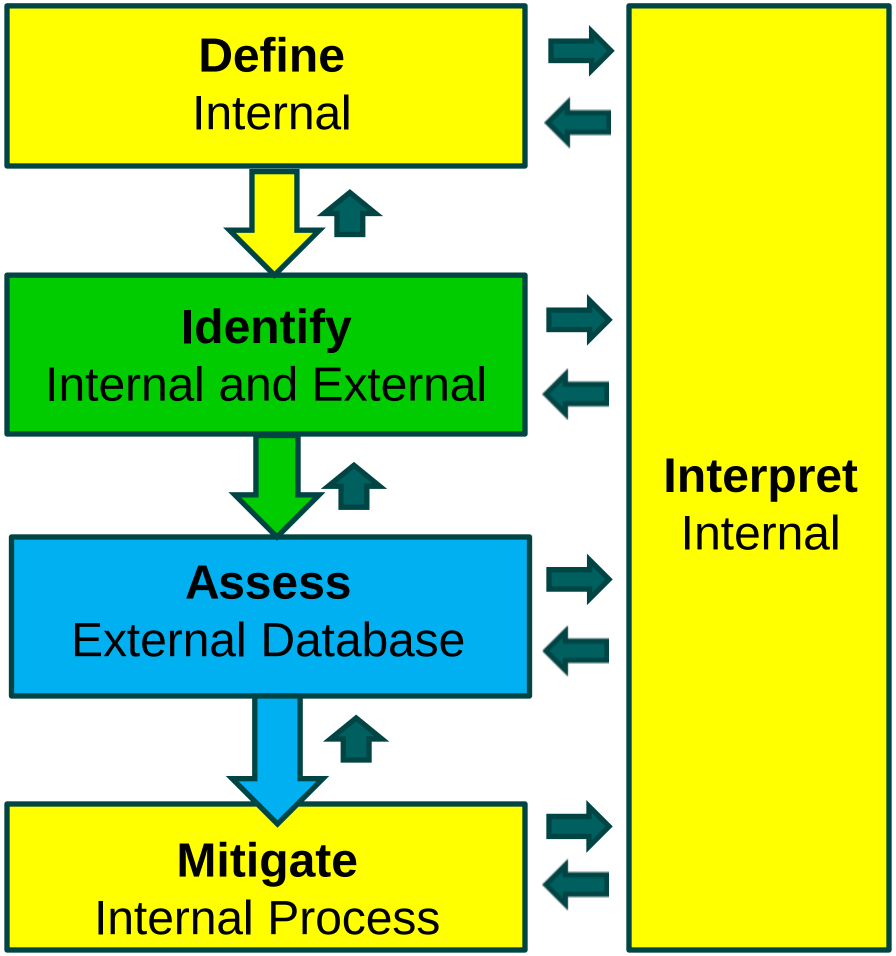
RARE EARTH ELEMENTS

- Decision support tool focus:
  - UK ‘green tech’ manufacturers
  - Rare Earth Elements
- Will consider both upstream and downstream risks
- Will be time sensitive to current and future risk levels
- Will use both internal and external data
- Will integrate with existing company processes
- Support decision of most appropriate mitigation strategy
  - Financial, technical, operational etc.

Manufacturing Supply Chain Resilience

IMPLEMENTATION OF FRAMEWORK – TOOL (FUTURE WORK)

- Define study
    - Written document with guidelines
- Identify risk
    - Qualitative and quantitative - computer aided
- Assess risk
    - External Database
- Mitigate
    - Internal processes



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Technical Seminar Series

Eco-Intelligent Manufacturing

TBC

16:00-17:00 26 March & 30 April

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