Circular Data

an essential enabler to boost the transition towards a more resource productive circular economy at scale

RESOURCE MANAGEMENT WEEK

2024

UNECE

Agenda

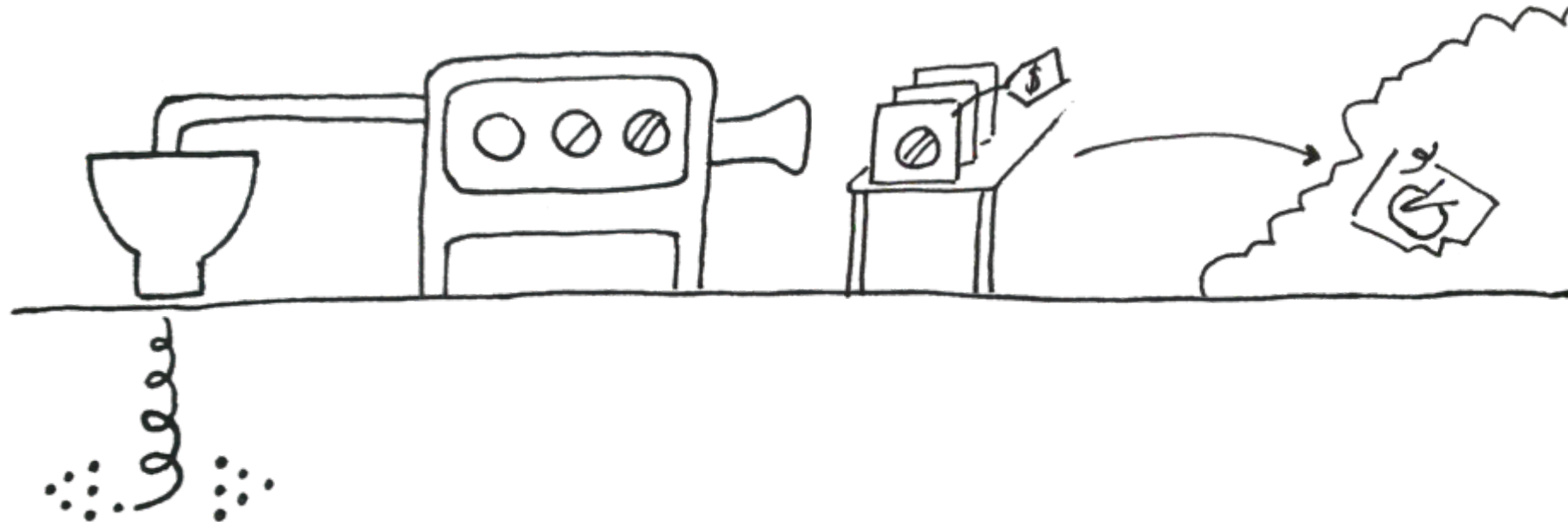**Core drivers and principals of a Circular Economy**

Limits of growth of a linear economy

Core drivers and principles of a Circular Economy

Circular Data pooling to boost circular resource management

Proposed next steps – global information system

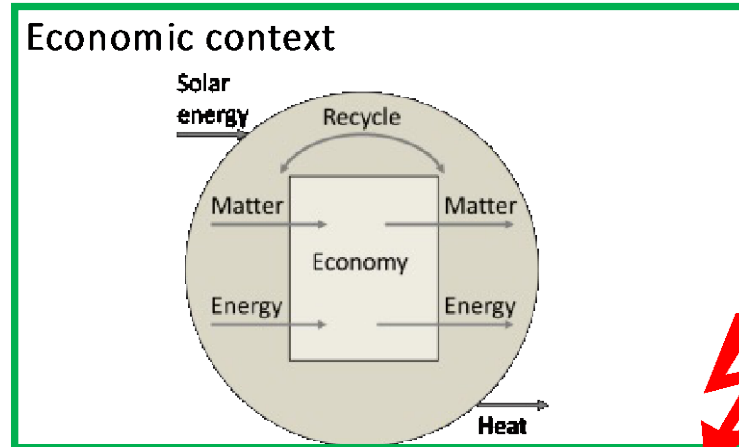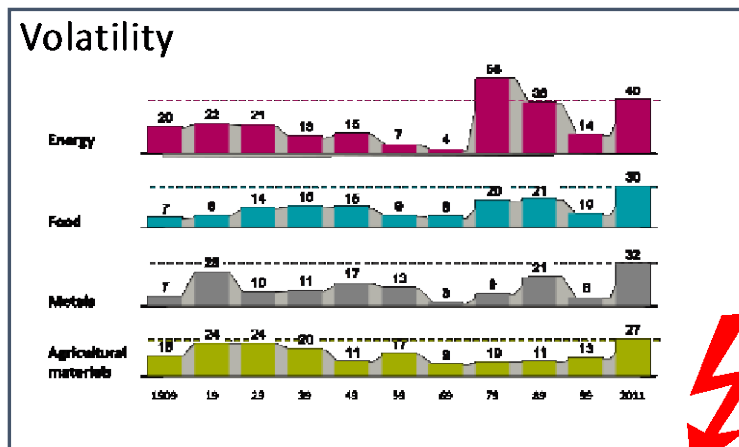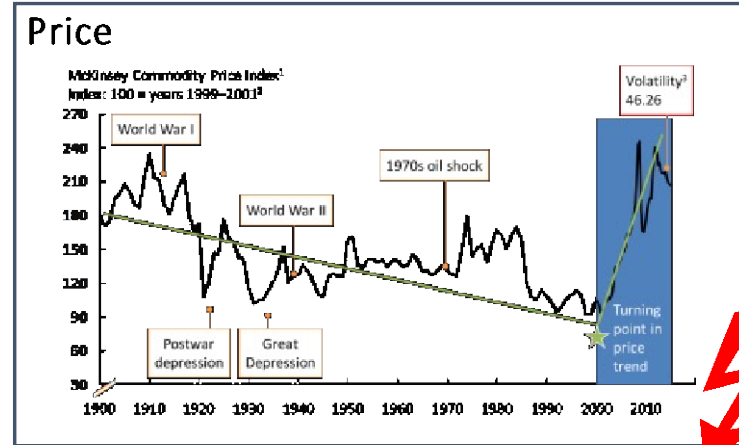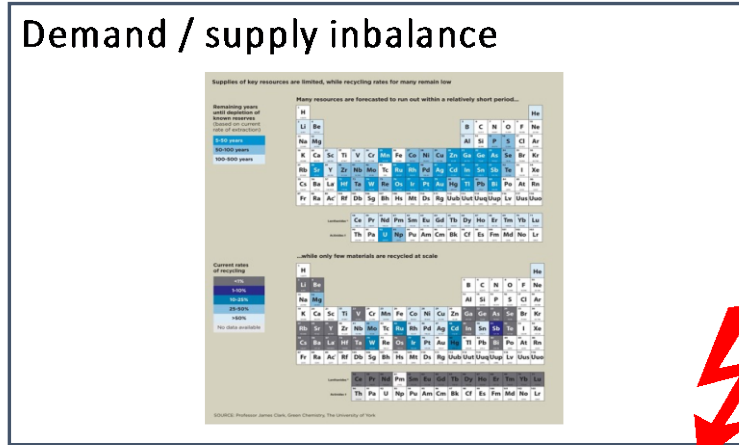# Our starting point – the linear economy

Source: Ellen MacArthur Foundation circular economy team

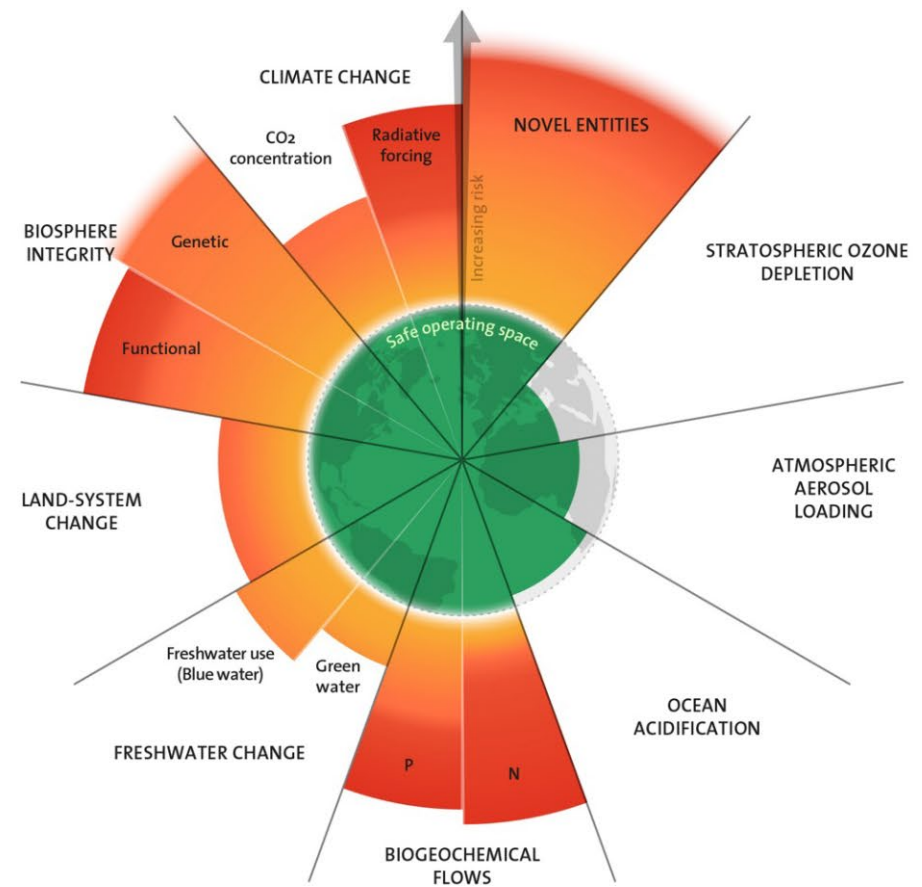# The challenge - symptoms of linear economic distress

Source: Ellen MacArthur Foundation circular economy team

The systemic nexus - resources and carbon as sink and source constraints for our economic activities
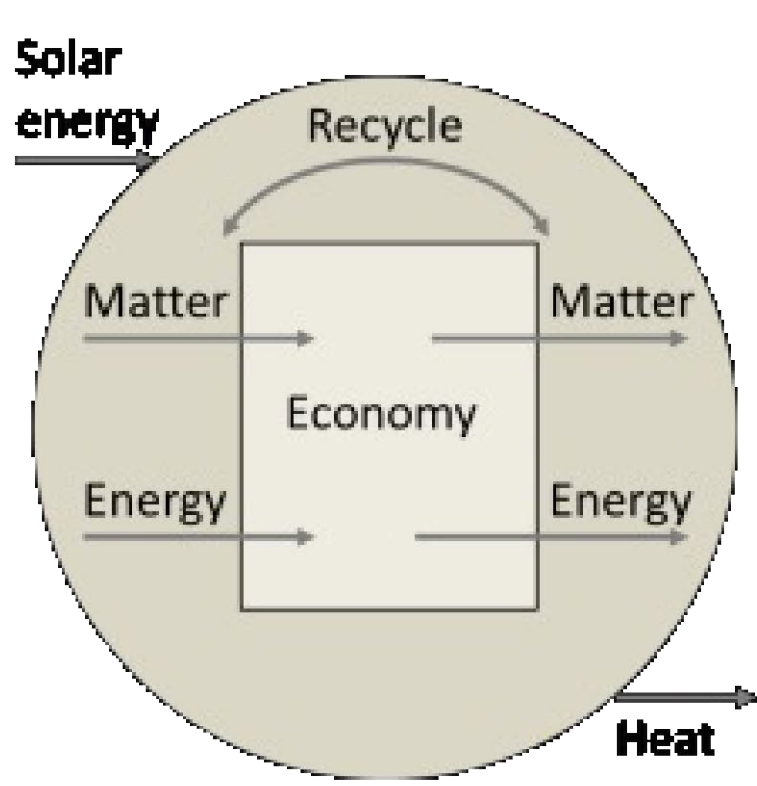
Agenda

Core drivers and principals of a Circular Economy

Limits of growth of a linear economy

Core drivers and principles of a Circular Economy

Circular Data pooling to boost circular resource management

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The big, simple idea - go circular

		Carpet	Fridge	Furniture
Linear system	**Resource intensity** Annual average change	+3%	-2%	-2%
	Market growth Annual average	+7%	+8%	+5%
Circular system	**Assumed no. of lifecycles**	2	3	4
	Material intensity Reduction potential	**-50%**	**-67%**	**-75%**

The circular economy model – flows and stocks

Biological materials

Technical materials

Mining/materials manufacturing

Farming/collection[1]

Biochemical feedstock

Restoration

Biosphere

Parts manufacurer

Product manufacturer

Service provider

Recycle

Refurbish/remanufacture

Reuse/redistribute

Biogas

Cascades

Maintenance

Anaerobic digestion/composting

Consumer

User

Collection

Collection

Extraction of biochemical feedstock[2]

Energy recovery

Leakage—to be minimized

Landfill

1 Hunting and fishing
2 Can take both postharvest and postconsumer waste as an input

SOURCE: Ellen MacArthur Foundation circular economy team

The baseline: Circular Economy starts with a look at the (existing) stocks and flows in use

Inflow → Usage → Outflow

Material focus

utilisation

stock in use

inflow

outflow

time
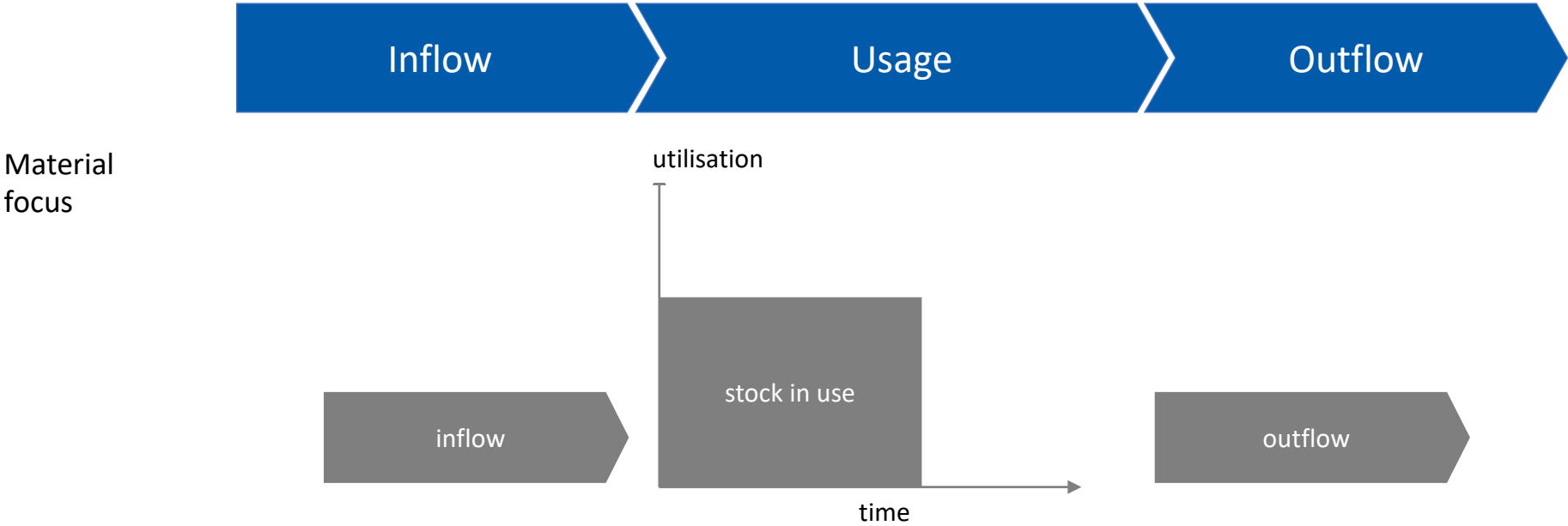
The nexus - between material stocks and flows and environmental impacts and footprints
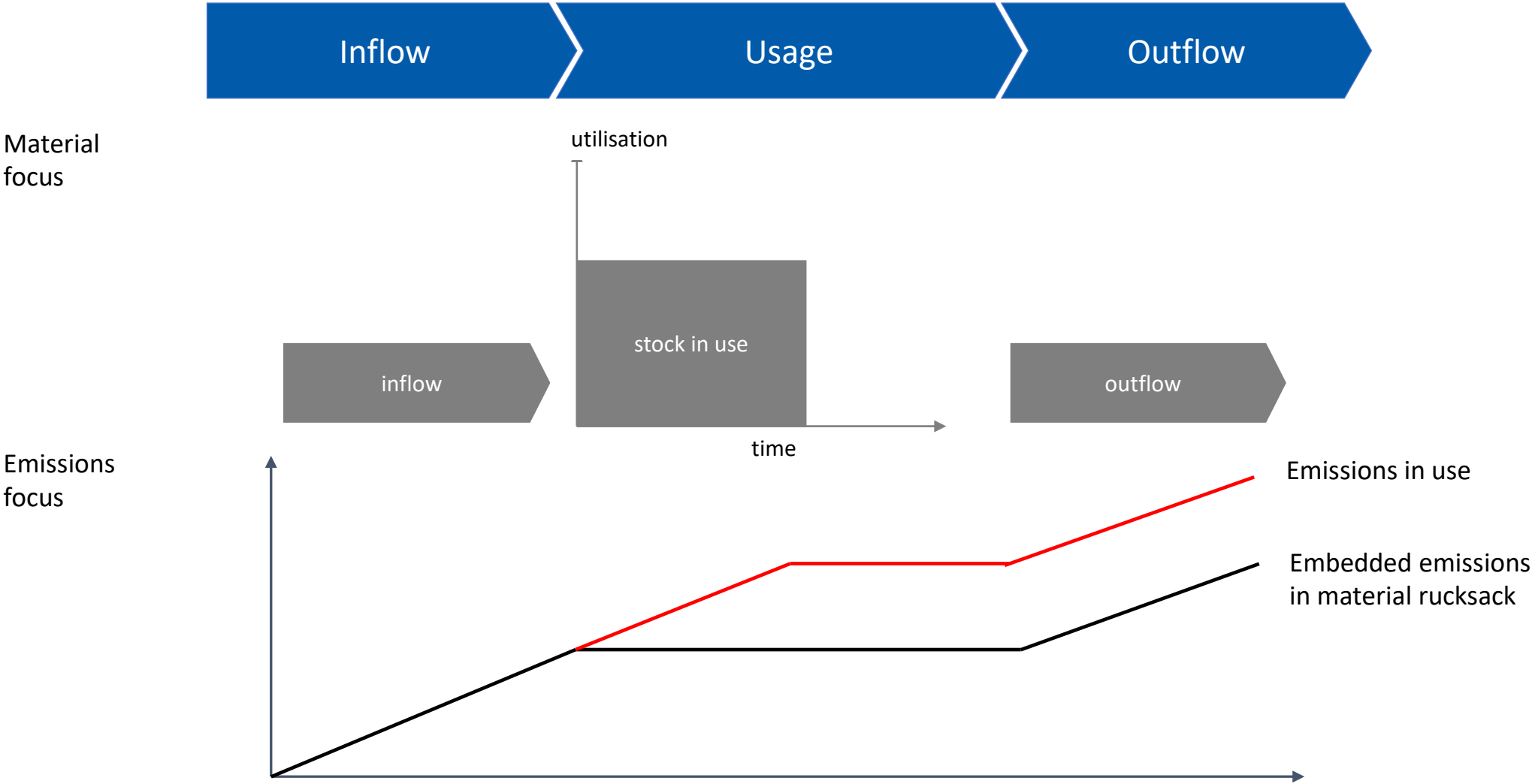
SOURCE: UEBS UKRI-CE-Hub

Step 1: Prolongation of use reduces need for material in- and outflow on a given stock

SOURCE: UEBS UKRI-CE-Hub
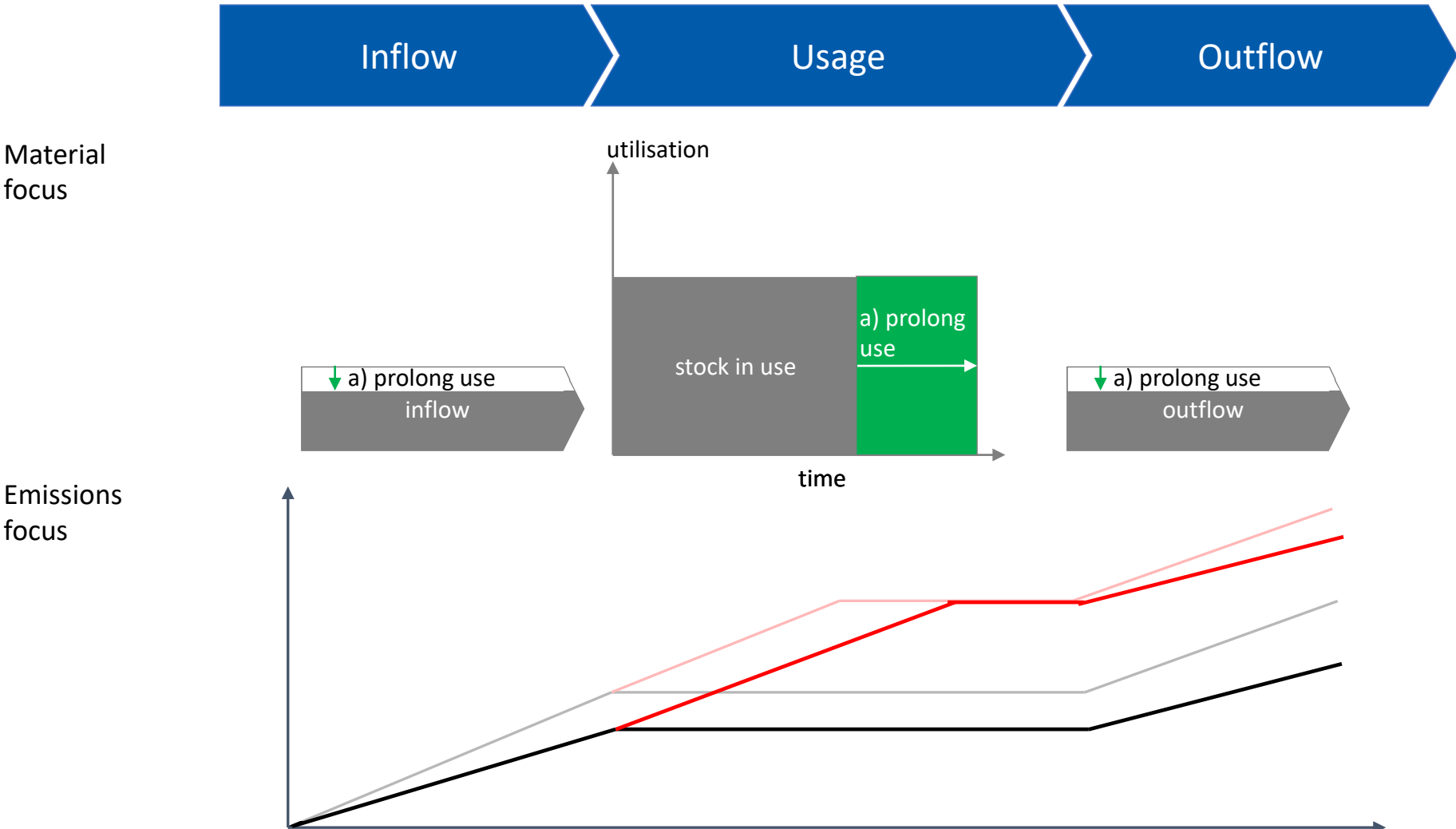
Step 2: Intensification of use delivers higher output at lower material intake
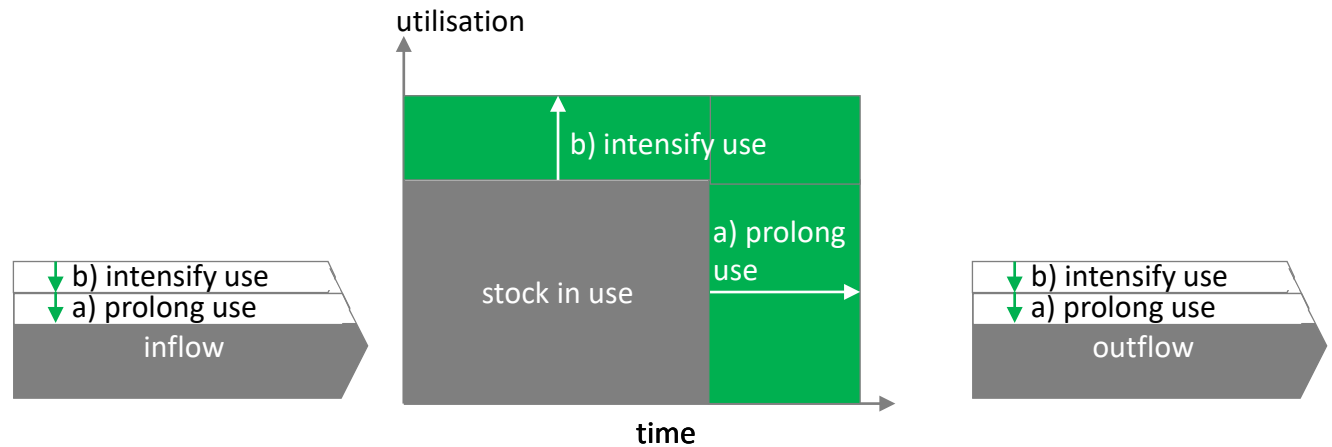
SOURCE: UEBS UKRI-CE-Hub
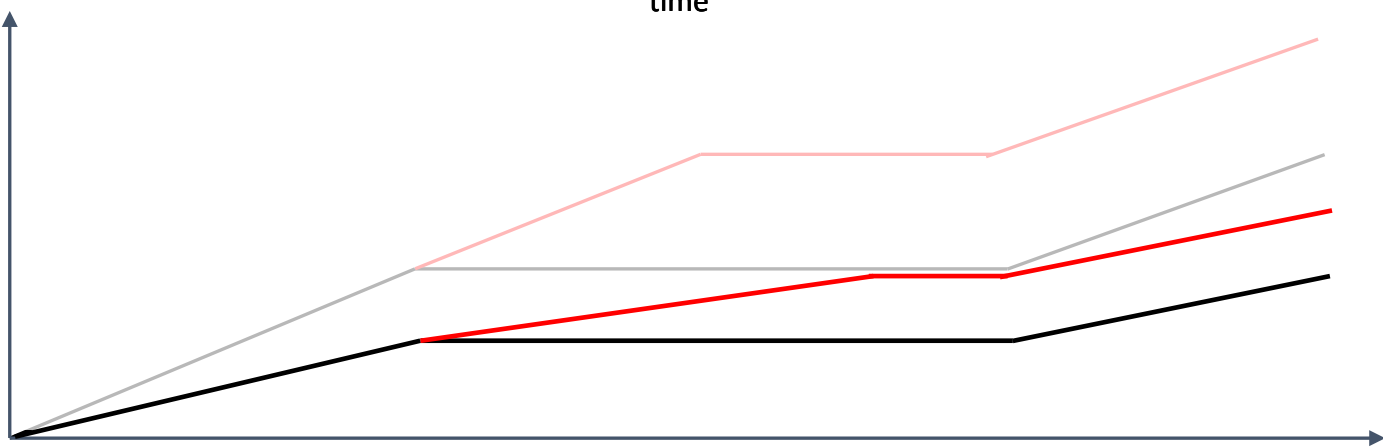
Step 3: Adding revalorisation of end-of-use flows further decreases material intake and landfill

SOURCE: UEBS UKRI-CE-Hub

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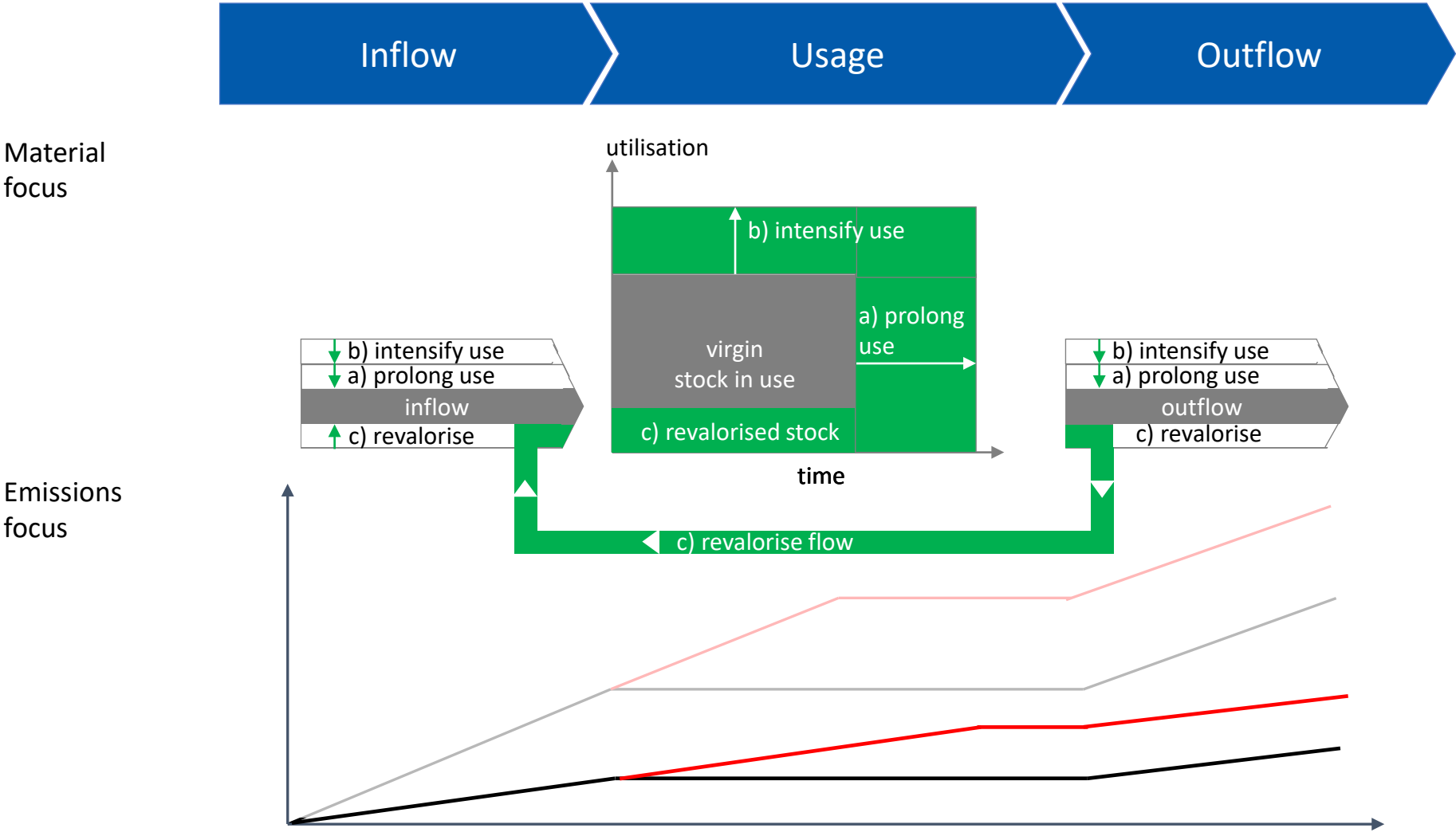
Step 4: Improving inflowcan further improve resource productivity and environmental performance

SOURCE: UEBS UKRI-CE-Hub
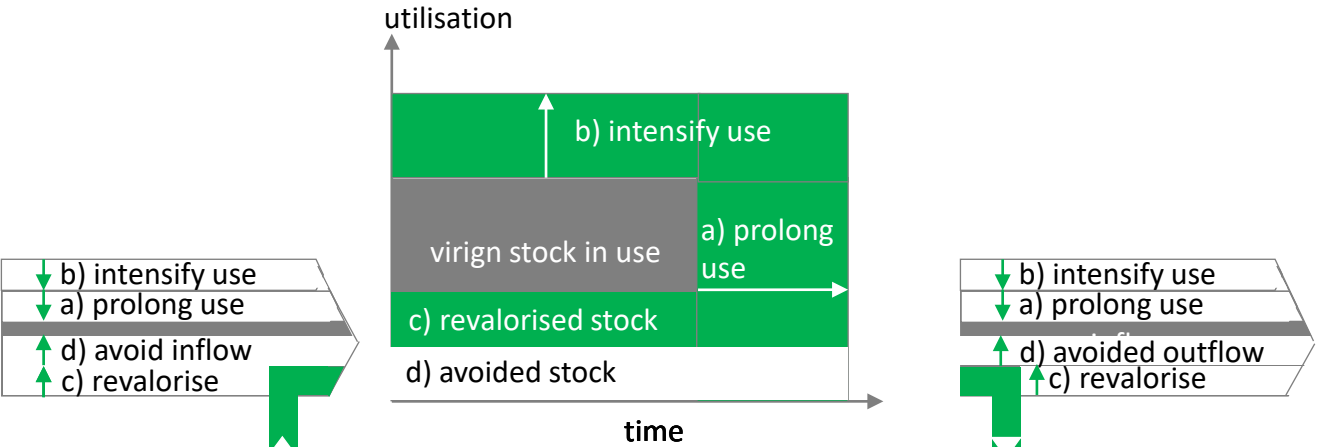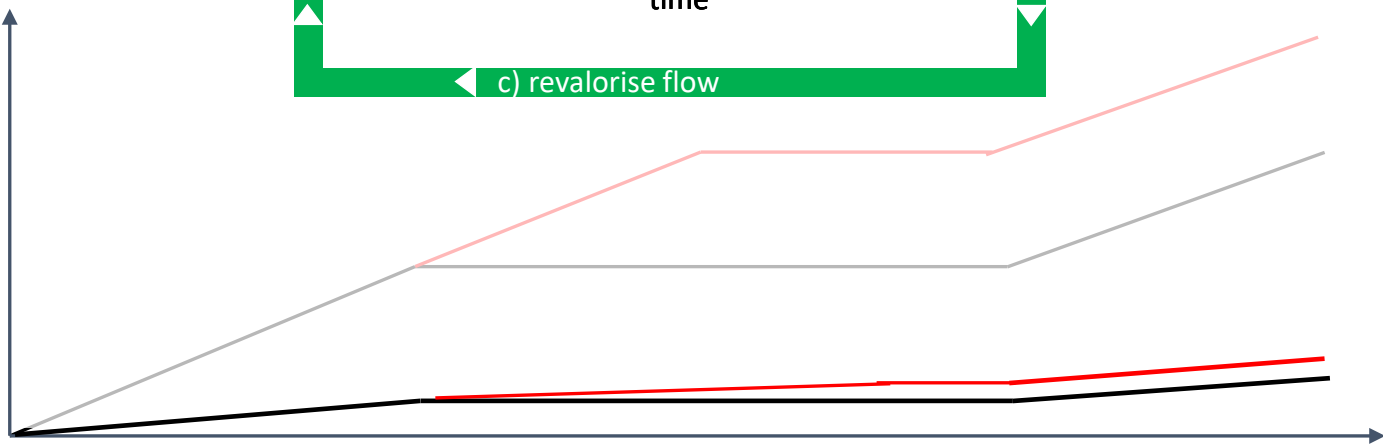
Compound impact of core CE-levers can deliver non-linear value creation and abatement potential

SOURCE: UEBS UKRI-CE-Hub

Winning strategies – CE-levers focus on systemic decoupling

Baseline

Given linear take-make-dispose systems configurations stock for productive use need to be replenished and processes after end-of-use at a high rate of throughput

1 Improve utilisation

Improving intensification and prolongation within the use phase, reduces significantly the in- and outflow at systems level
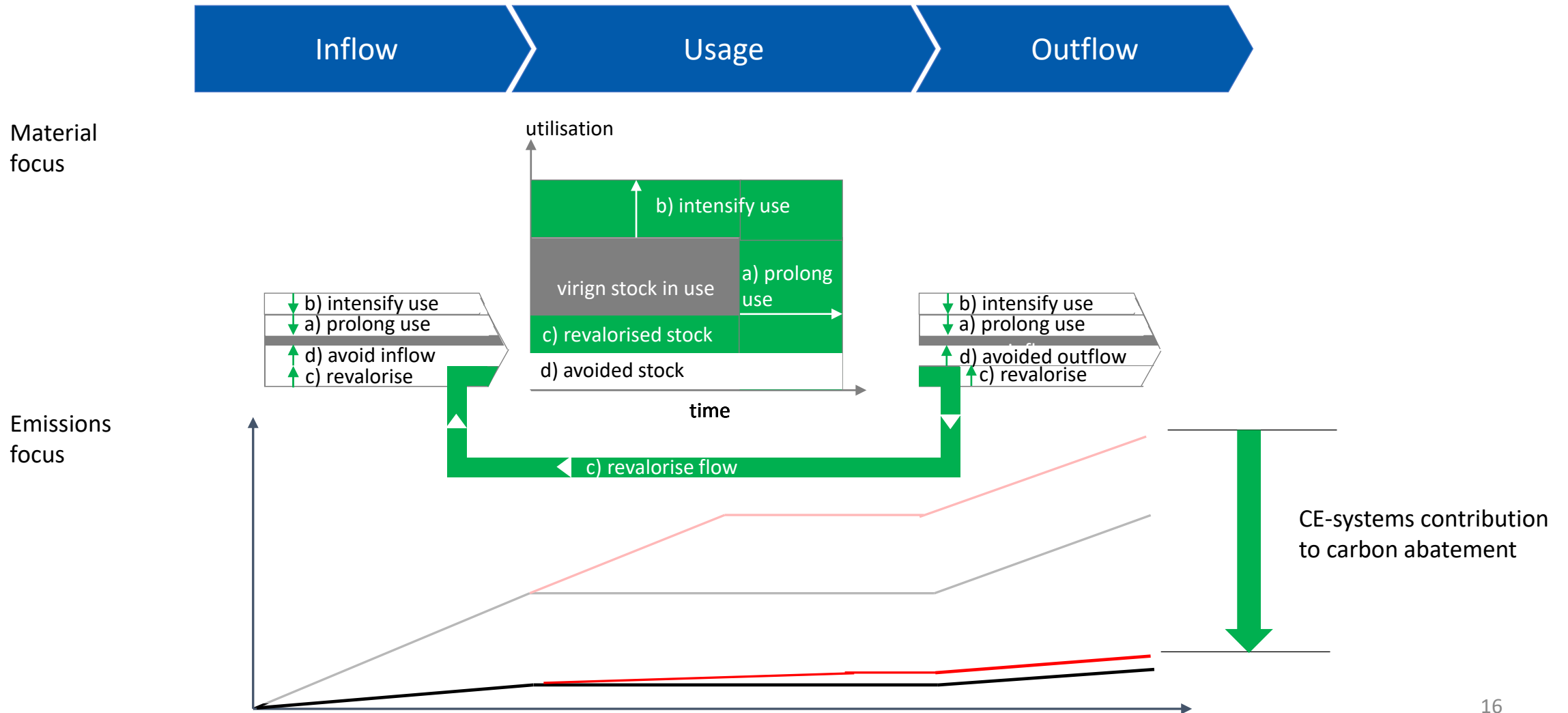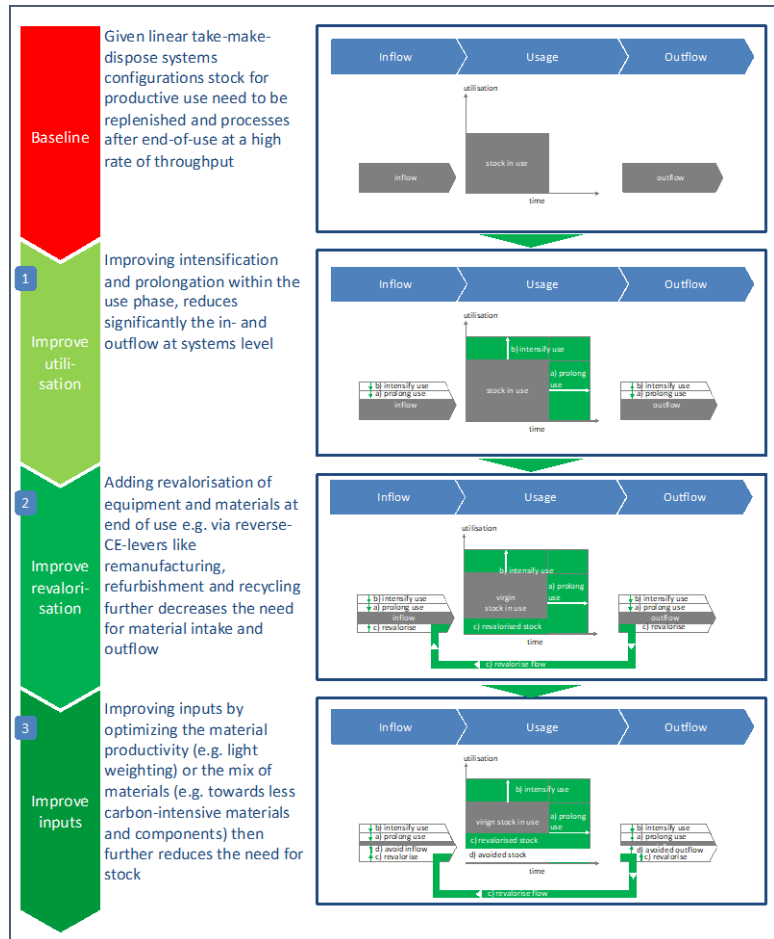
2 Improve revalorisation

Adding revalorisation of equipment and materials at end of use e.g. via reverse-CE-levers like remanufacturing, refurbishment and recycling further decreases the need for material intake and outflow

3 Improve inputs

Improving inputs by optimizing the material productivity (e.g. light weighting) or the mix of materials (e.g. towards less carbon-intensive materials and components) then further reduces the need for stock

Typical winning strategies, CE-Interventions and policy instruments

a. Product life extension: Consumer rights and education, Extended warranty and burden of proof, right to repair, durability labels, eco-designs, …

b. Intensify use: product-as-a-service models, sharing business models, community provided services, ….

c. Revalorise: Take-back-schemes, extended producer responsibility schemes, 9R-toolset, improved collection and separation technologies, optimized gate-pricing to minimize leakage, improved policing of waste and environmental protection, post-use material marketplaces, simplified trade regulations, …

d. Optimize inflow: eco-design regulation, incentives to minimize material proliferation and BOM complexities, improved material choices, tagging and tracking, dematerialisation, …

SOURCE: UEBS UKRI-CE-Hub

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Core drivers and principals of a Circular Economy

Circular Data pooling to boost circular resource management

The resource management challenge

Our approach – pooling of Circular Data

Proof of value – UK test case

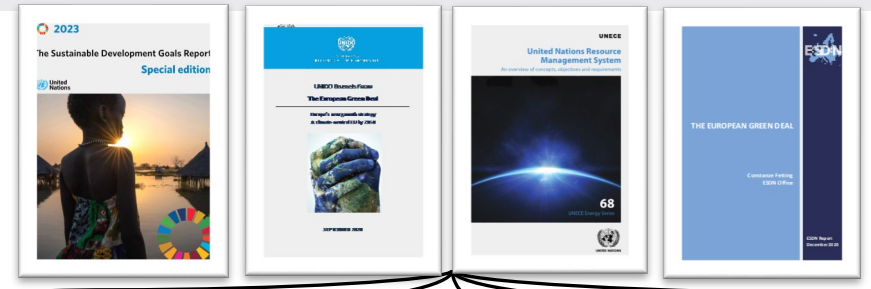Proposed next steps – global information system

Achieving global policy priorities will require more productive management of resources

Strategy/ utility layer

Product layer

- buildings
- Electric vehicle
- Wind turbine
- Health Care
- infrastructure

100 of thousands product (types)

(Nested, multi-tier) component layer

- solar panel
- Battery pack
- REE-motor
- Turbine blade
- PCB
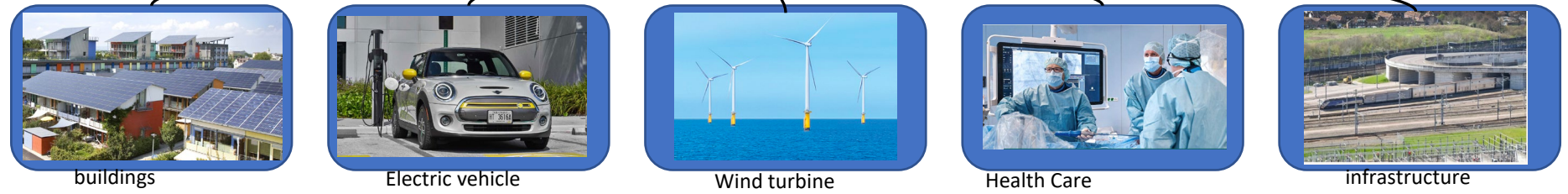
Billions of compo-nents (types)

(Raw) material layer

- Lithium
- Dysprosium
- Neodymium
- Copper
- Zinc
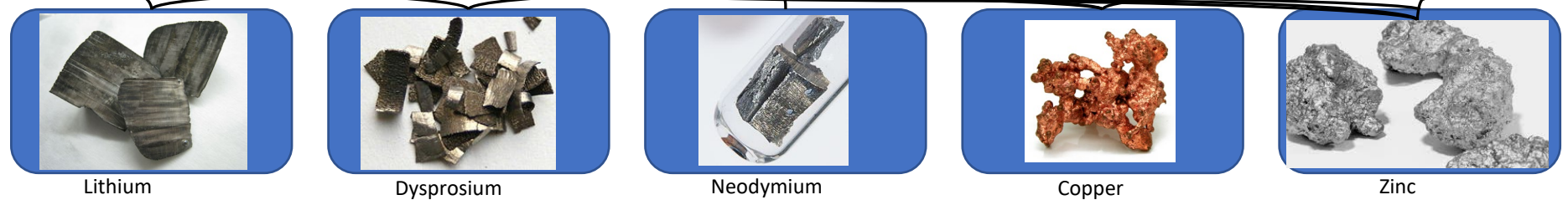
118 elements

UK test case focused on decarbonization technologies using REE PM motors

Strategy/ utility layer

Product layer

... buildings | Electric vehicle | Wind turbine | Defence equipment | infrastructure ... | 100 of thousands product (types)

(Nested, multi-tier) component layer

... solar panel | Battery pack | REE-motor | Turbine blade | PCB ... | Billions of compo-nent (types)

(Raw) material layer
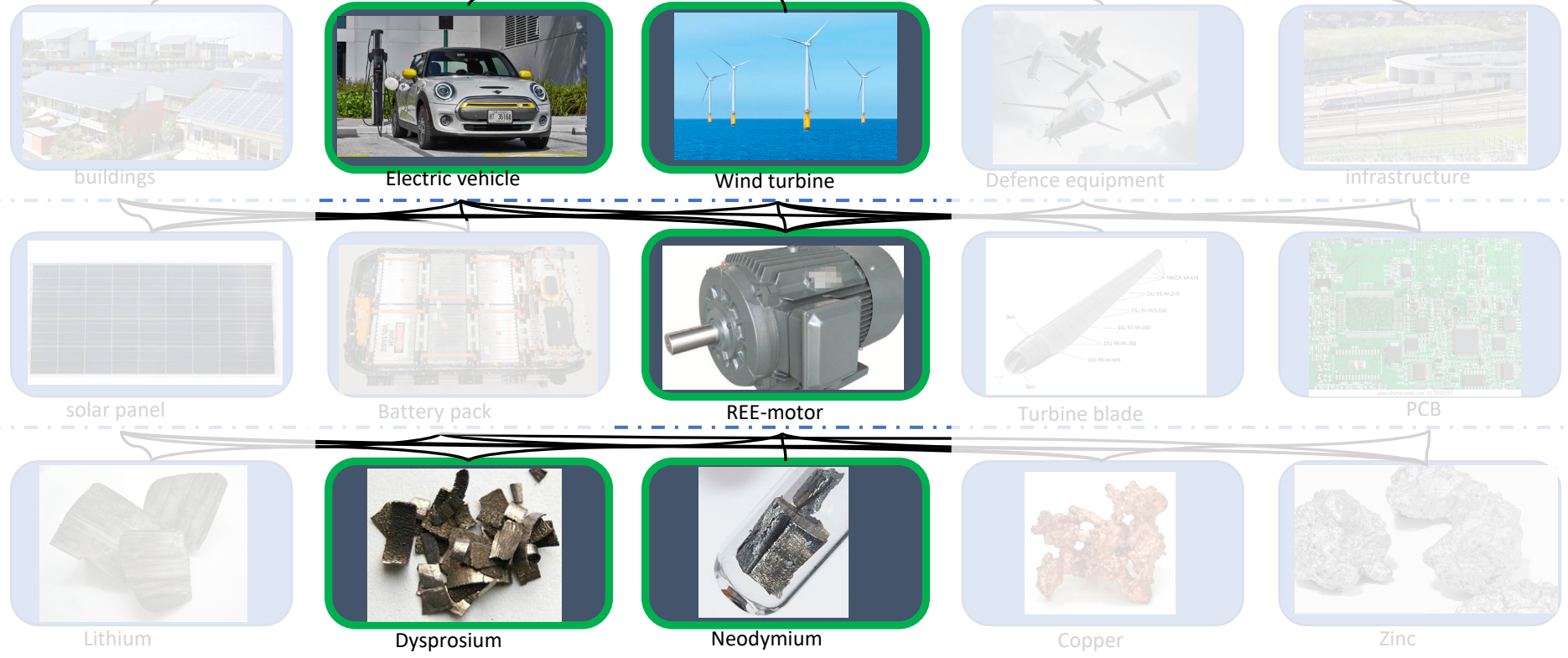
... Lithium | Dysprosium | Neodymium | Copper | Zinc ... | 118 elements

Typical approach is based on targeted one-off requests

analysts

Analysts ...

policy question

How to build supply chain resilience with international raw material dependencies

How best to provide in-use or post-use regulation to avoid material leakage

Is there a viable business case for a global/national REE revalorisation industry?

... ponder **specific policy questions**...

derived information need

What is the quantity and value of REE product stock in national economy by 2030,2040, 2050?

What products and materials to the REE end up in?

How big are the investment requirements for projected inflow of post use REE?

... which need to be **translated into customised data requests** ...

required data sets

volumes stocks

values & prices

Billl of materials

Exter-nalities

volumes stocks

activity costs

volumes flows

Business Model data

...for which **suitable data sets need to be procured** (often from private sector sources)

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Overcoming the current linear project-driven data model

New policy question identified

Analytical project refined & data requirement identified

Data usage negotiated

Data available

Outputs disseminated

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

Analysts engaged

Data acquisition commences

Data engineered and linked

Analysis undertaken in protected environment

Project closes

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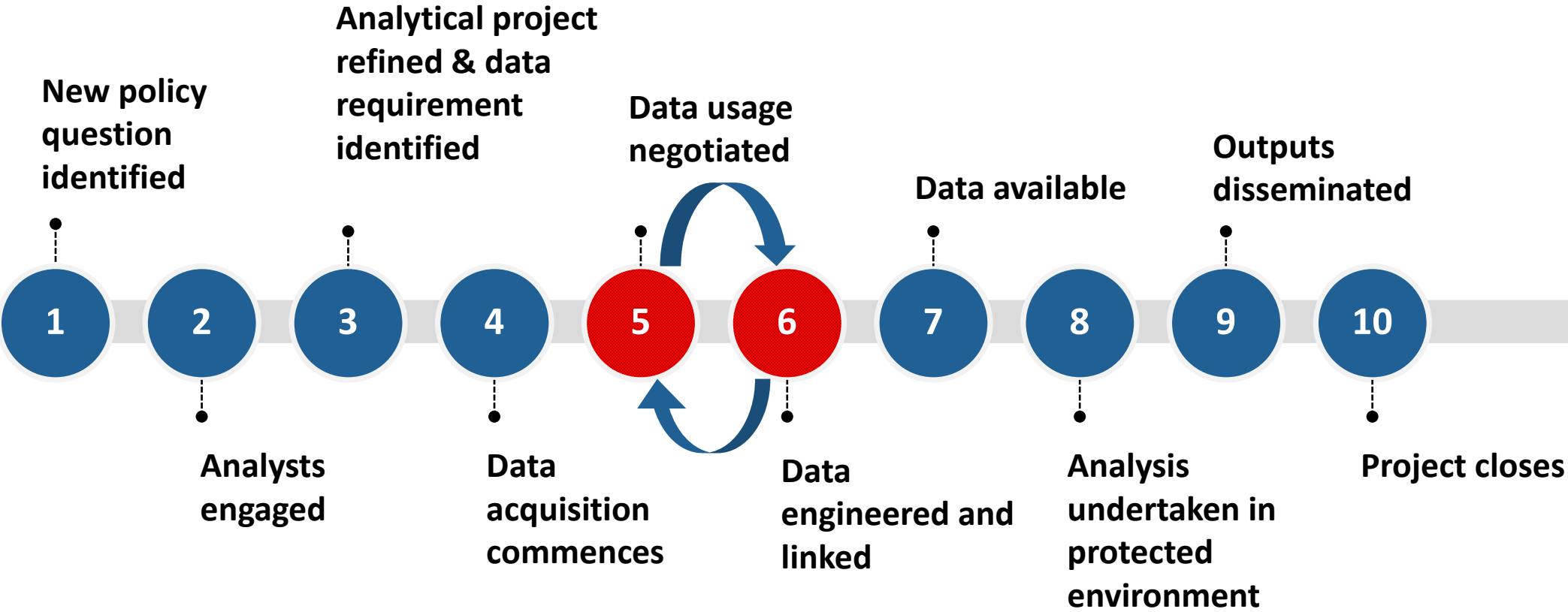
Current practice drives up data cost and limits effectiveness
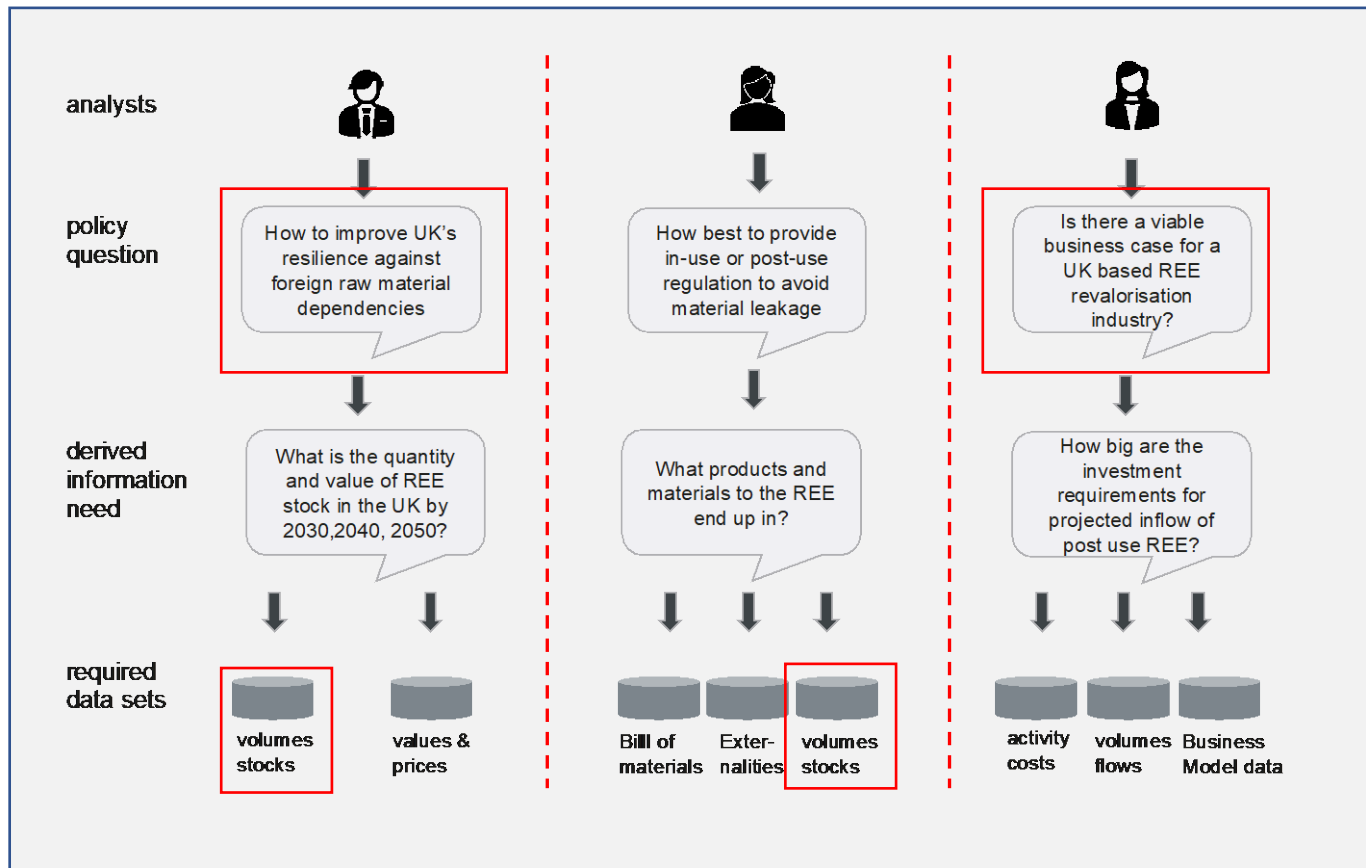
Analysts have complex problem-solving needs, but need to **rely on static, largely historic focused inquiries with long turn-around times**

Different departments consider related questions in silos with the **risk of inconsistent and ineffective conclusions** and recommendations

Translation of information needs to be focused on selected aspects and **risks under-leveraging potential resources**

Data acquisition for one-off requests is costly and time consuming, in general not reusable and potentially redundant

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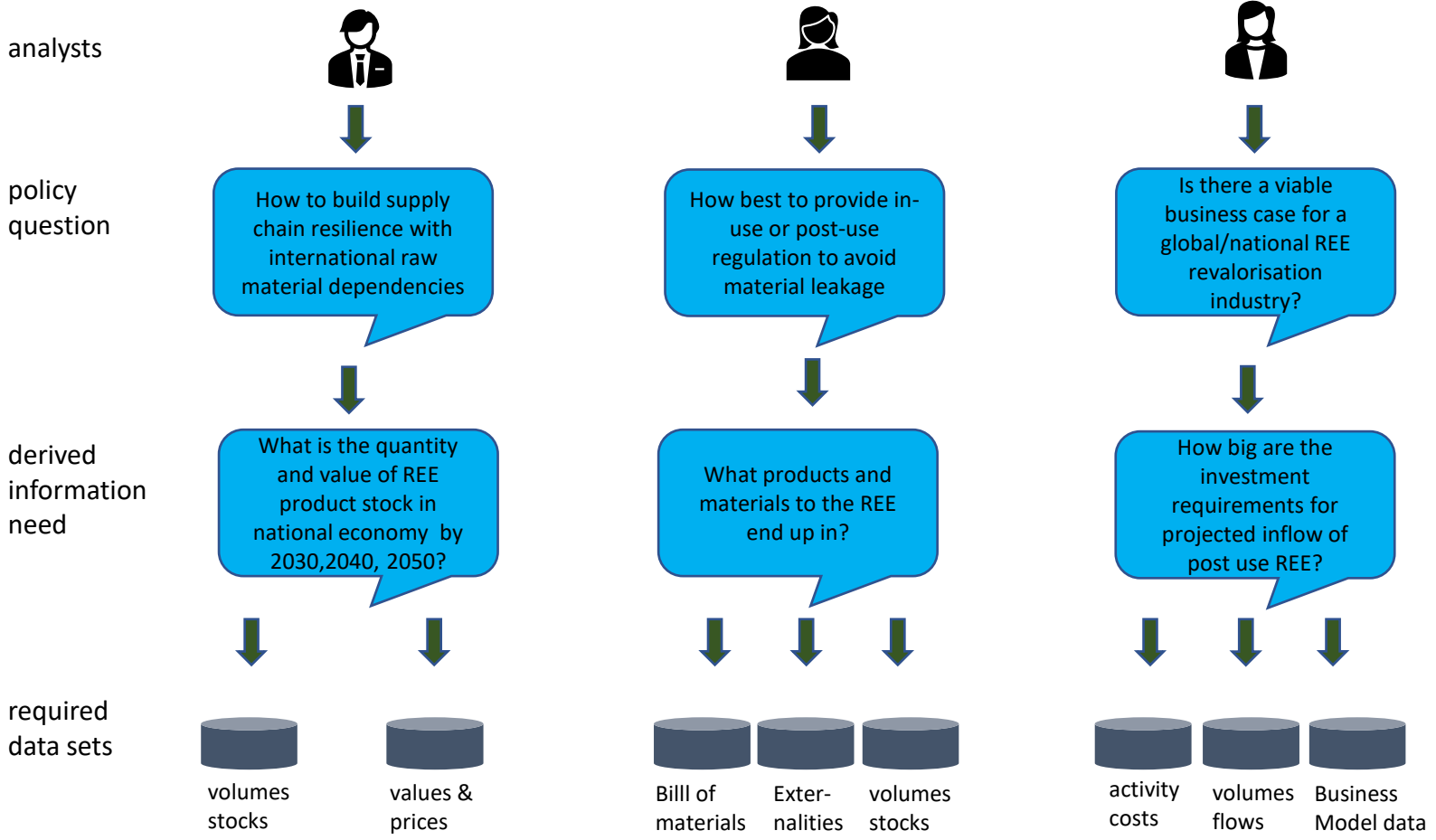**Our approach – pooling of Circular Data**

Proof of value – UK test case

Proposed next steps – global information system

# Typical approach is based on targeted one-off requests

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Business Model data

…for which **suitable data sets need to be procured** (often from private sector sources)

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Our approach addresses these issues with few targeted innovations
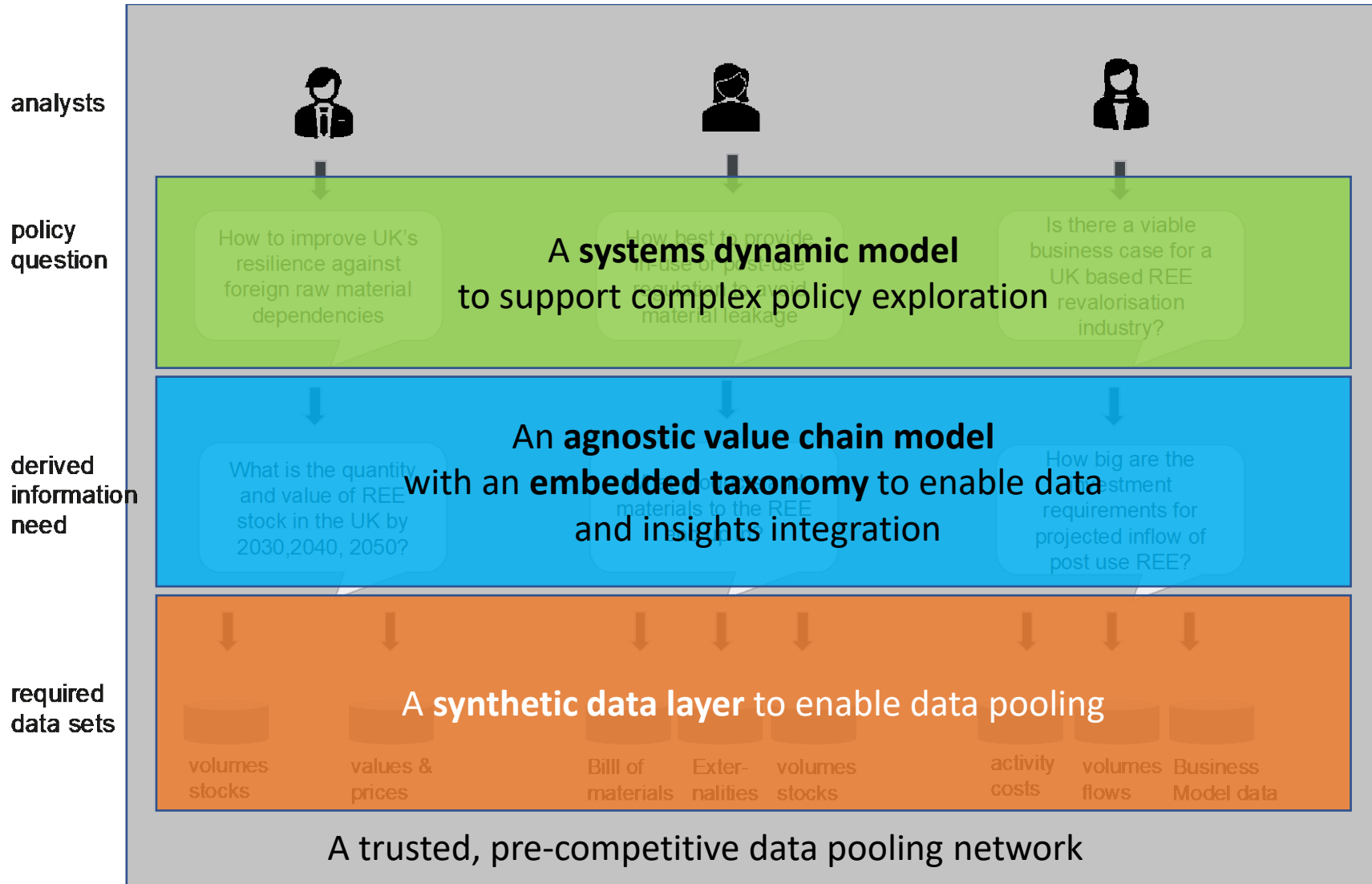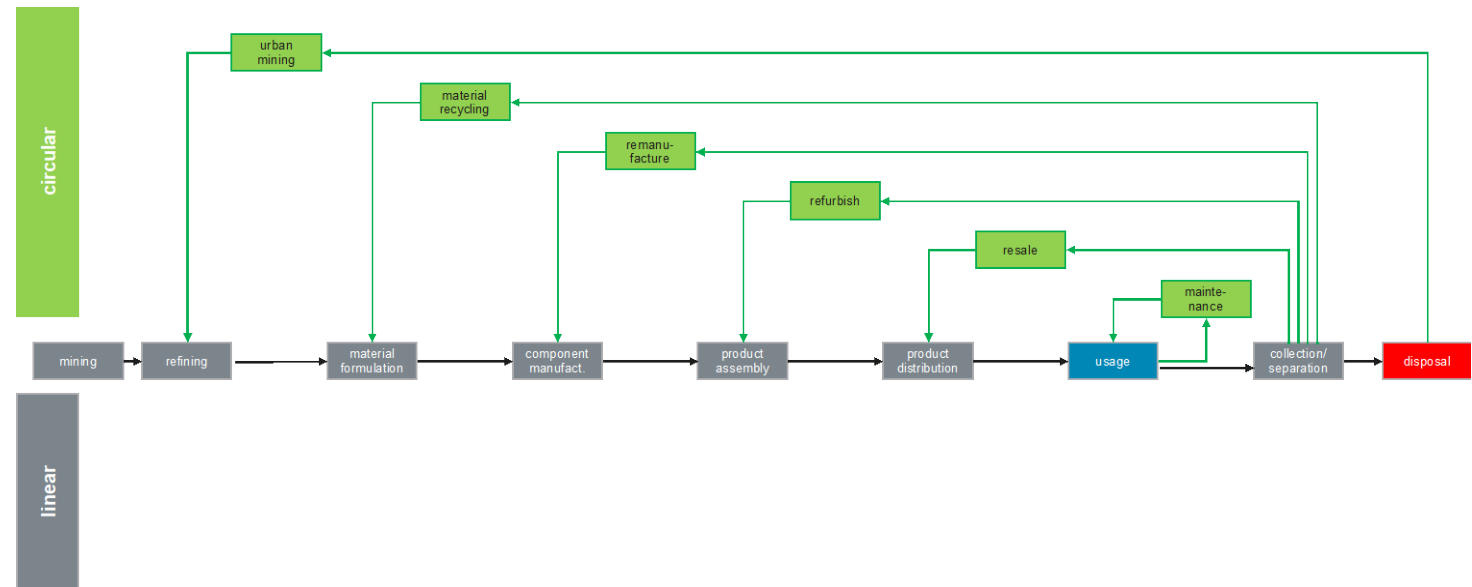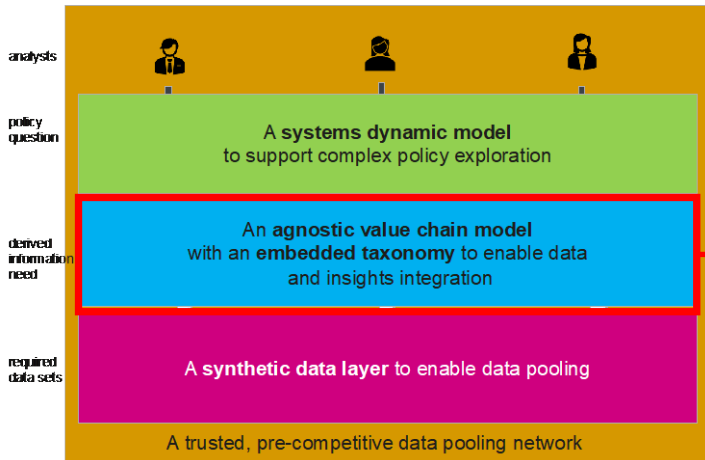
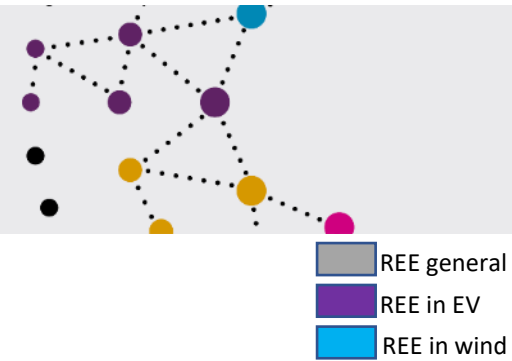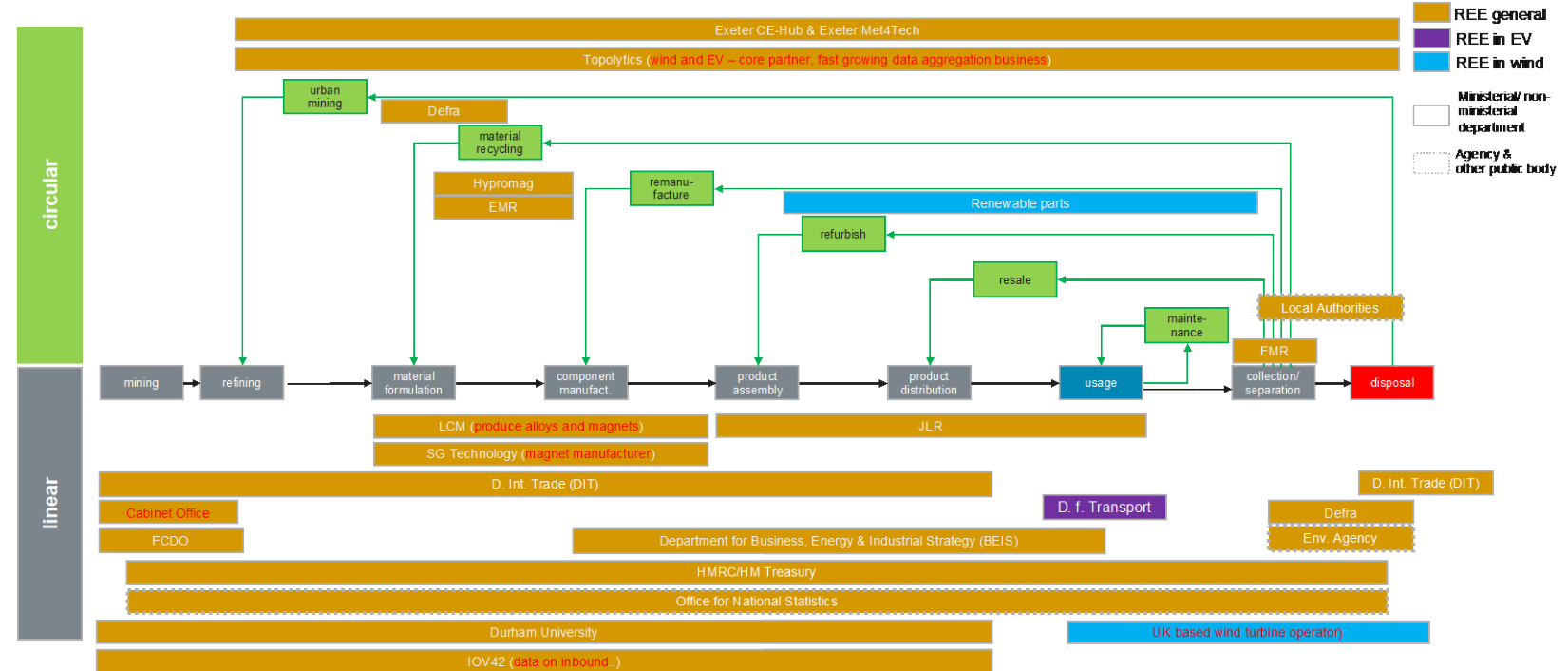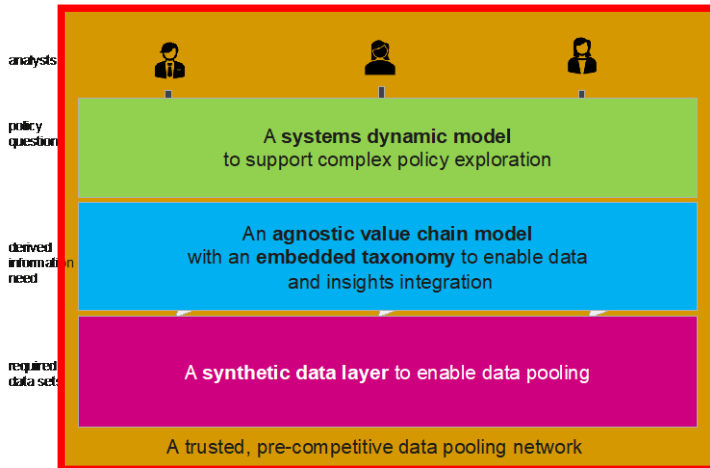Representation of bio-physical flows along agnostic value chain model important to create consistent framework

- to account for different levels of product aggregation from material to component and final products
- to provide structure to link data assets to certain activities, stocks and flows and actors into a comprehensive data pool
- To enable systemic analysis for shifts in underlying bio-physical flows in policy design for an increasingly interconnected (circular) economy

CE-hub with track-record in testing this for relevant other focus areas beyond REE PM

Mapping known research and data sources prioritises data pooling needs

Legend:
- REE general (grey)
- REE in EV (purple)
- REE in wind (blue)

circular / **linear**

Sources (circular, upper): DEMETER, REE4EU, CEWASTE, CRMR

Sources (right upper): EV Trends, CEWASTE, CRMR, CE legal framework, EERE

Sources (linear, lower): CSyARES, REIA, ERMA

Process flow (circular): urban mining → material recycling

Process flow (linear): mining → refining → material formulation → component manufact. → usage → collection/separation → disposal

Additional nodes: refurbish, resale, mainte-nance

Private sector unknown secret sauce Bermuda triangle: no codification on typical refurbishment and remanufacturing processes and costs as either performed in non-standardised, highly fragmented grey markets or deemed competitively differentiating amongst contractual IP protected B2B relationships

BOM-complexity and traceability challenge: countable and traceable materials get absorbed in the BOM complexity as proliferation of components and products exceeds traceability and sufficient alignment of interest amongst competing private sector stakeholders

Forming minimum-viable consortia of public and private sector actors along the agnostic value chain model provides basis for full-coverage of all relevant aspects with knowledgeable experts, who can provide data assets and contribute to data pooling effort

Building data layers at product and materials scale enables data integration

Taxonomy allowing standardisation and integration of different data assets
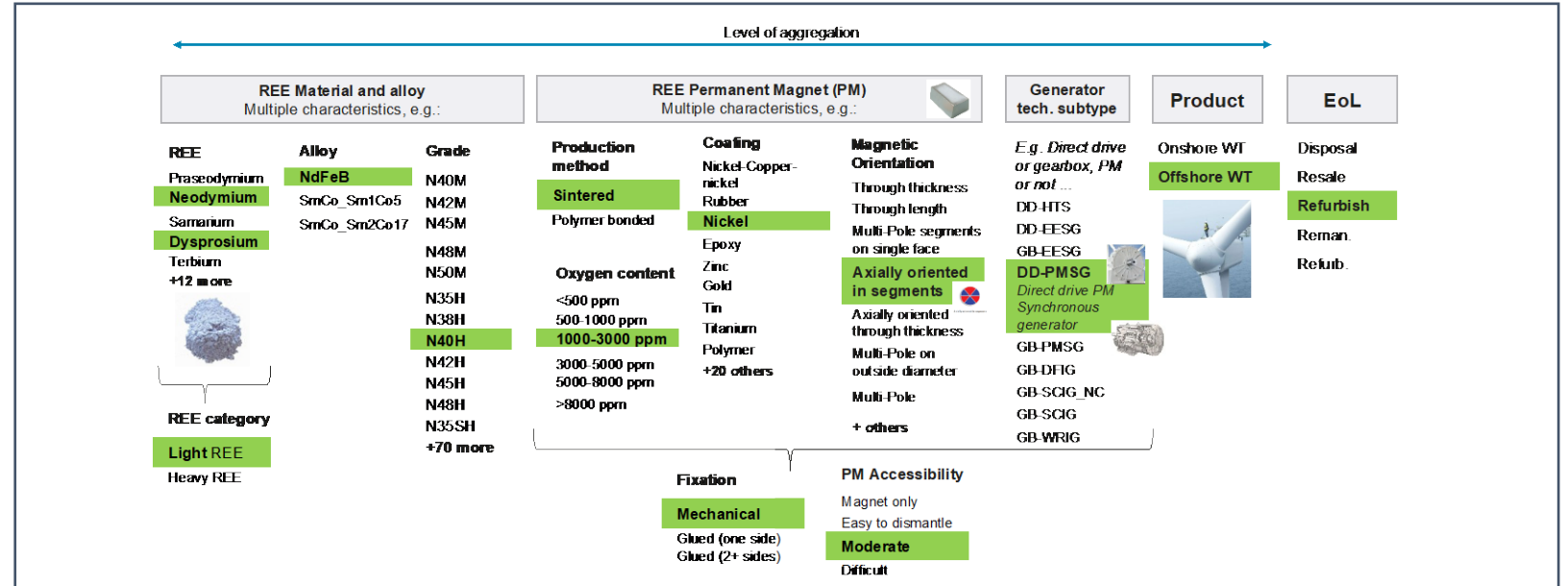
Compiling synthetic data layer in which different data assets can be integrated and reused

Material-types | Bill of materials | signature elements | product usage | volumes flows | volumes stocks | values & prices | Value chains | Geo-spatial data | activity costs | Exter-nalities | Business Model data
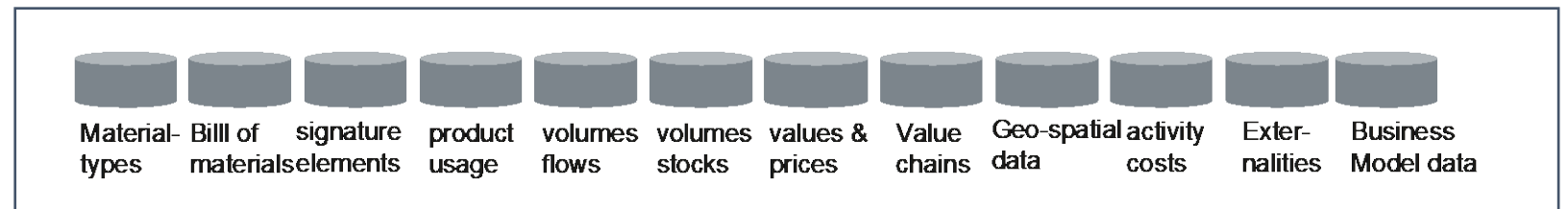
42+ data-pools pooled into synthetic data layer

The left panel diagram:

- analysts
- policy question
- derived information need
- required data sets

A systems dynamic model to support complex policy exploration

An agnostic value chain model with an **embedded taxonomy** to enable data and insights integration

A **synthetic data layer** to enable data pooling

A trusted, pre-competitive data pooling network
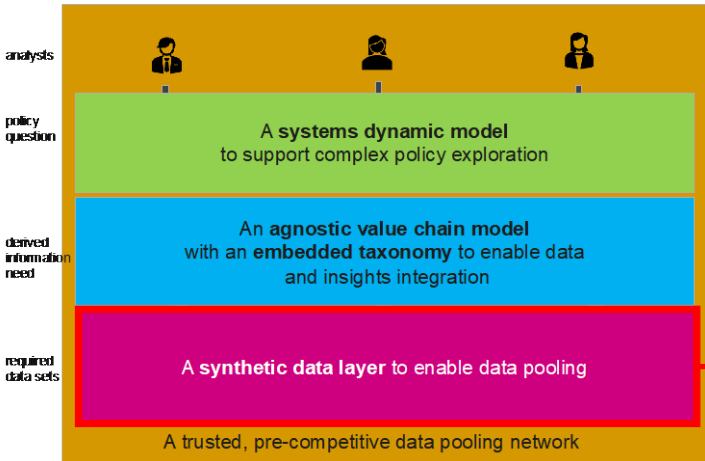
A data pool comprises public and secondary data

- **Leveraging different data sources** for the data pool along core elements of agnostic value chain and taxonomy
  - publicly available data assets
  - hidden, non-linked data assets
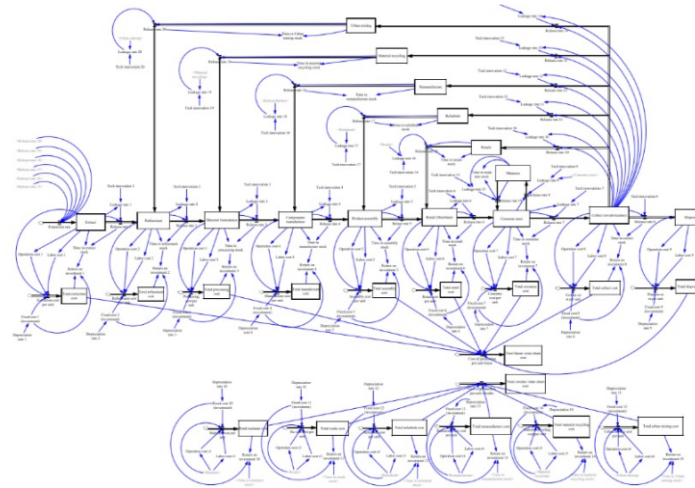 - private sector data assets

- Public data assets are **systematically augmented** with
  - private sector insights on hard to get data (e.g. bill of materials)
  - **continuously embedding previously searched data** assets into synthetic model

- Approach enables **new connections and cross-validation** of different sources to
  - **improve overall quality**
  - **at reduced cost**

Adding a systems modelling layer facilitates data exploration
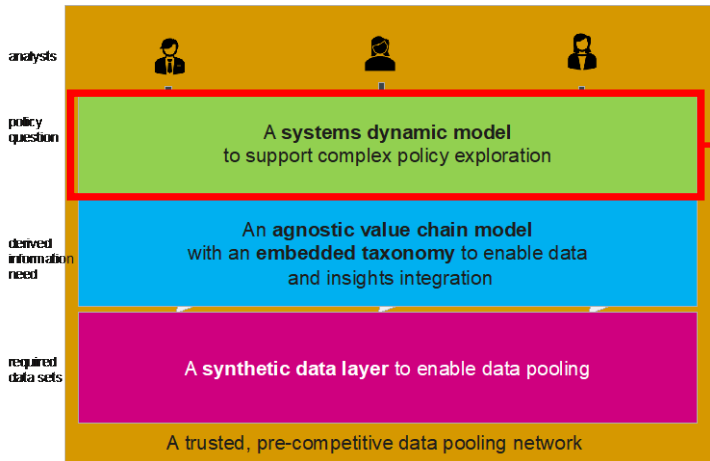
Scenario-based business dynamics model...

... will be used to evaluate core KPIs for UK CE-systems performance

- analysts
- policy question
- derived information need
- required data sets

A **systems dynamic model** to support complex policy exploration

An **agnostic value chain model** with an **embedded taxonomy** to enable data and insights integration

A **synthetic data layer** to enable data pooling

A trusted, pre-competitive data pooling network

- Demand vs. supply forecasts — Demand / Supply
- Best reverse option — Lifet. ext. Reman. Refurb. Recycle Disposal
- Load across value chain
- UK value capture potential — GBP

- Linked business dynamic model with cost and emissions layer
- Capable of modelling target and transition states over time
- What-if-analysis allows simulation of non-intuitive systems performance

- Outputs can be linked to dashboard layer to facilitating diagnostics and representation for policy engagement
- Comparative analysis of different options frequently more important then isolated proof of hypothesis via static data requests

Adding intuitive GUI enables faster exploration by analysts
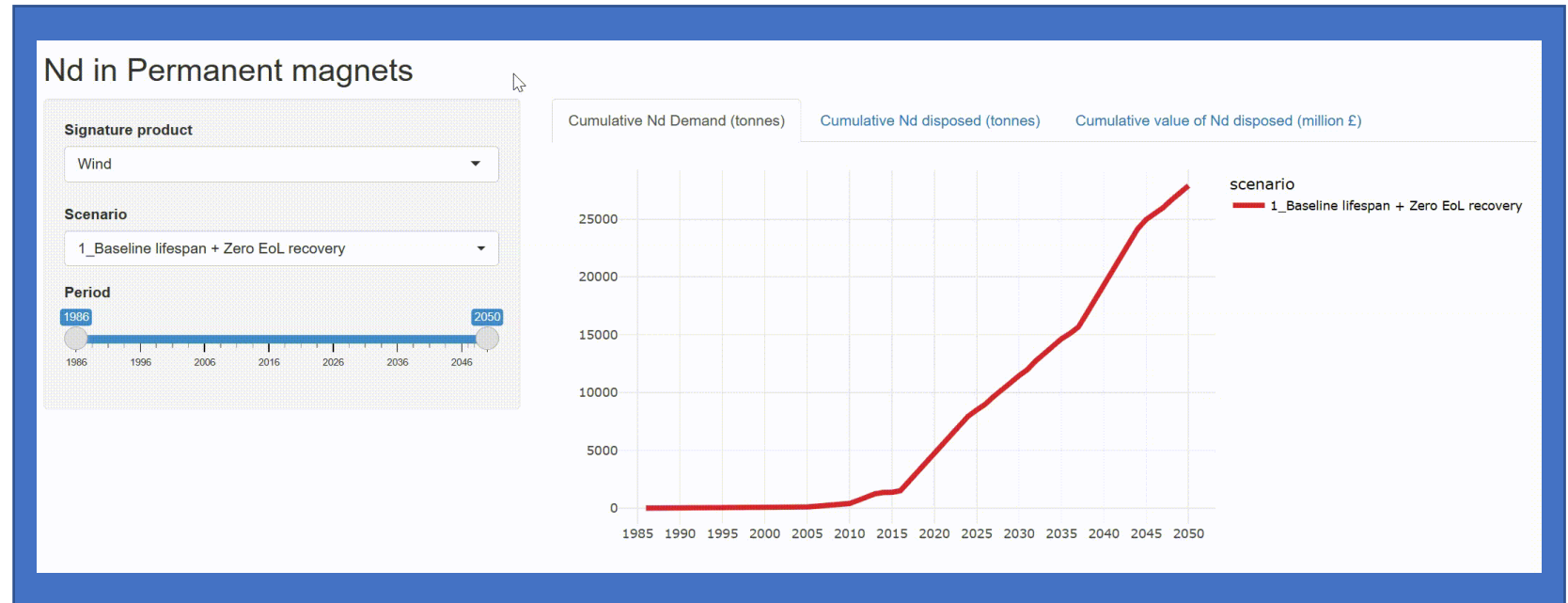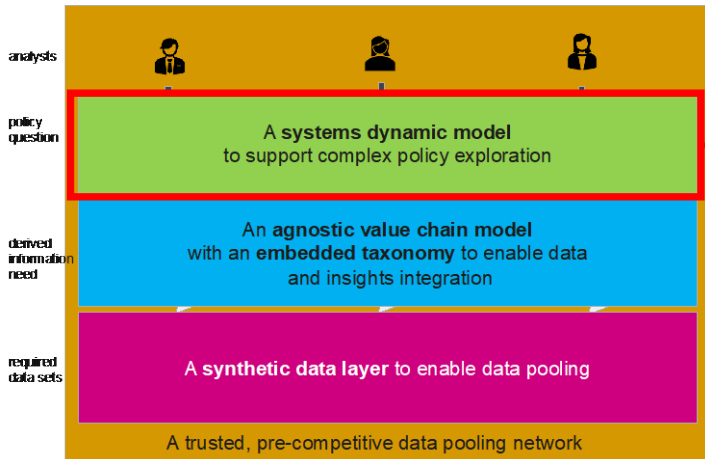
- Intuitive front-end and dashboard linked to business dynamics model allows multi-criterial interactive exploration of the solution space and systems performance

- Sensitivity analysis of combined policy interventions displays significant potential for UK-value capture for the Wind and EV-post use revalorisation

- Powered by business dynamics model capable of projecting impact of CE-interventions over time

Multi-layer model architecture ensures scalability and scenario-readiness
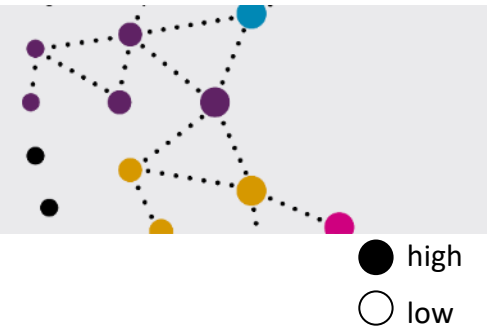
Diagnostic/ synthesis layer

Portfolio view · Value leakage view · Value chain view · pain-point view · externality view
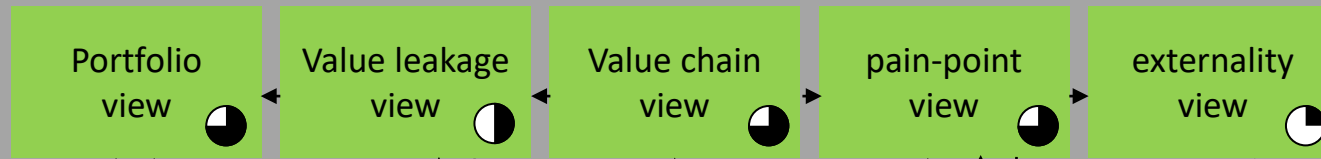
Standardised views with customisation potential

CE-systems exploration layer

CE- exploratory model (business dynamics model)
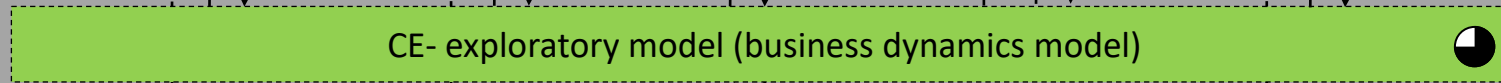
CE-systems- value driver layer

CE-interventions / value driver model

BOM-aggregation model / taxonomy · (reverse) value chain model · Geo-spatial model
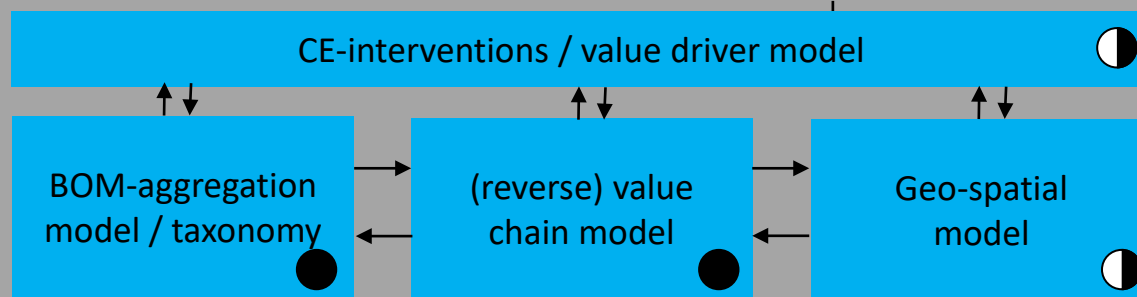
Agnostic CE-systems core

Data layer

Material-types · Bill of materials · signature elements · product usage · volumes flows · volumes stocks · values & prices · Value chains · Geo-spatial data · activity costs · Exter-nalities · Business Model data
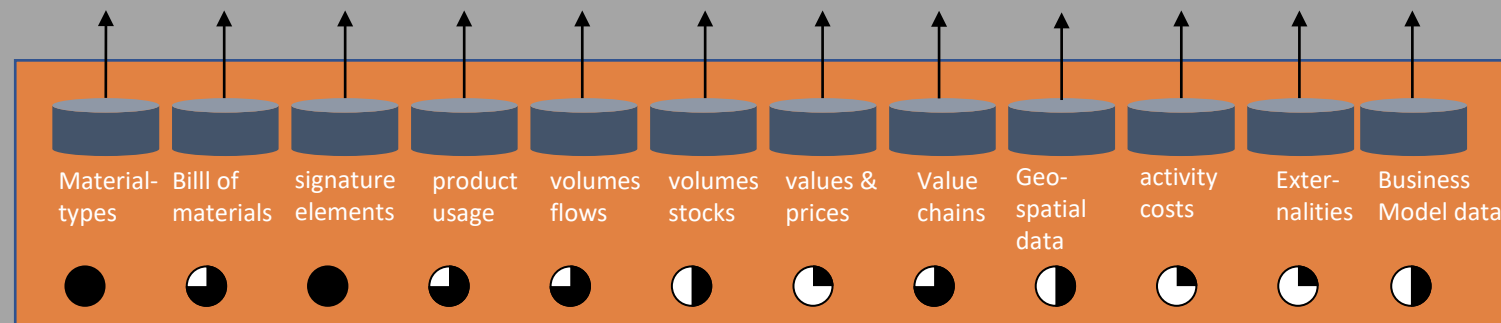
Application / domain specific data layer (with high potential for commonality at industry / sector level)

high · low

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Our approach – pooling of Circular Data

Proof of value – UK test case

Proposed next steps – global information system
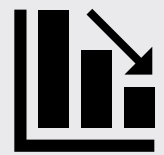
Simple policy questions can lead to complex research requests

Seemingly simple question ...

Department for International Trade

What will be the stock of Rare-Earth-Elements in the future?

Will we be able to recapture some supply via local revalorisation?

... but stressing fully our current capabilities

- **it is looking into the future** for an industry with virtually no historic data to derive trends from

- **it requires understanding at multiple data points** across the value chain

- **Some necessary data solely resides with private** sector entities

- **It requires judgement and scenario capabilities** to identify bandwidth and margin of error

- .... *(long list could be continued here)*

NICER PROGRAMME

UK Research and Innovation

Generated answer …

Expected stock and outflow of REE materials from EV and WP will accumulate by 2050 to

- *35.000 tons*
- *at a market value of 7.6 billion GBP at today's prices*

with UK-based capabilities a share of up to 10% of primary inflow could potentially be substituted

… leveraging core building blocks of our systems model

Demand forecast

➕

Material/technology mix

➕

Reverse capability assessment

➕

Market prices
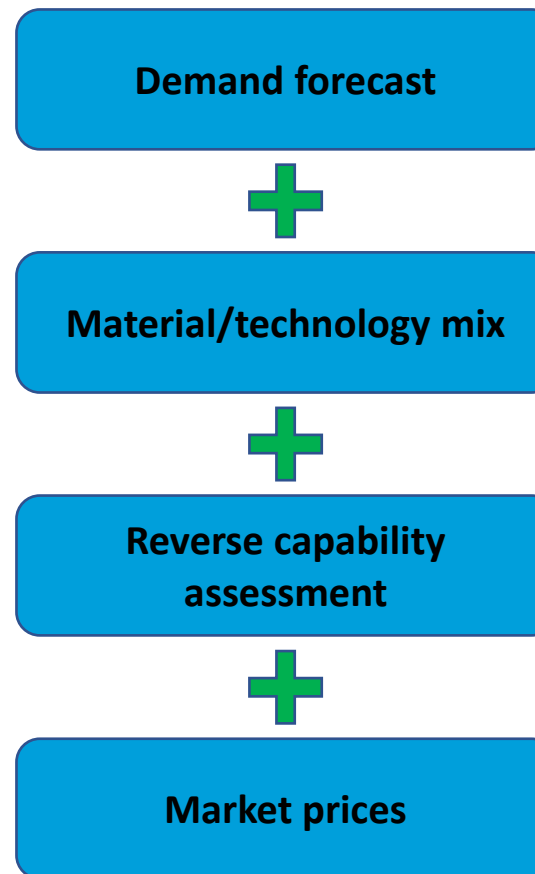
BENEFITS:

- Response time 2 weeks instead of month to a year ✓

- 0 GBP incremental costs vs. 250.000 GBP research spend ✓

- Clear set of reusable assumptions and consistent answer in next request ✓

- 3rd party resell value ✓
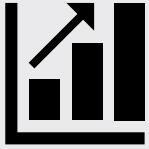
Analysis of economic recovery potential for the UK in excess of 7bn GBP

1. Projections for rare earth elements (REE) from EV motors and Wind turbines in the UK to 2050
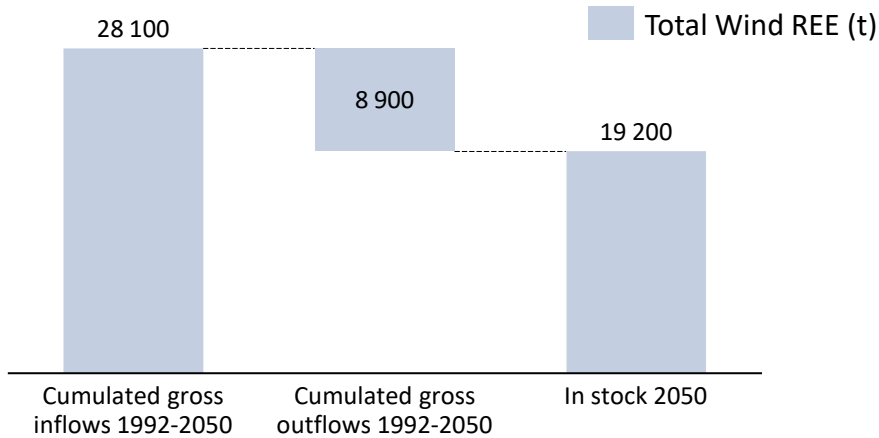
2. REE lost in outflow (1992-2050)*

Electric vehicles

Total EV REE (t)

- 47 200 — Cumulated gross inflows 2010-2050
- 25 500 — Cumulated gross outflows 2010-2050
- 21 700 — In stock 2050

25.500 | 5.400.000.000 → 100%

- Cumulated gross outflows 2010-2050 (t): Dysprosium (Dy) 13%, Neodymium (Nd) 87%
- Material value (GBP): Dysprosium (Dy) 31%, Neodymium (Nd) 69%

Legend:
- Dysprosium (Dy)
- Neodymium (Nd)

Wind turbines

Total Wind REE (t)

- 28 100 — Cumulated gross inflows 1992-2050
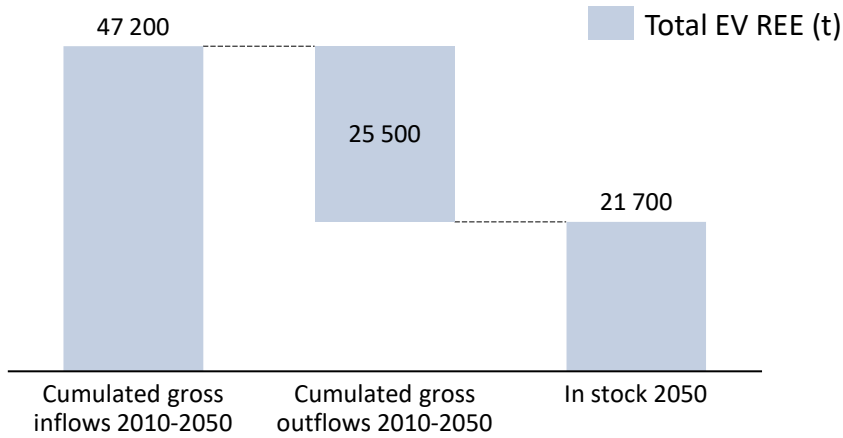- 8 900 — Cumulated gross outflows 1992-2050
- 19 200 — In stock 2050

8.900 | 2.350.000.000 → 100%

- Cumulated gross outflows 1992-2050 (t): Dysprosium (Dy) 8%, Neodymium (Nd) 76%, Praseodymium (Pr) 13%, Terbium (Tb) 2%
- Material value (GBP): Dysprosium (Dy) 15%, Neodymium (Nd) 49%, Praseodymium (Pr) 8%, Terbium (Tb) 28%

Legend:
- Dysprosium (Dy)
- Neodymium (Nd)
- Praseodymium (Pr)
- Terbium (Tb)

* Assuming no circularity (reuse, recycling, etc.). Material value at today's retail prices.

Wan-Ting, Hsu et al. 2023, „Mapping the flows and stocks of permanent magnets earth elements for powering a circular economy in the UK, Sustainable Production and consumption

Agenda

Core drivers and principals of a Circular Economy

Circular Data pooling to boost circular resource management

Proposed next steps – global information system

What we have learned

Observation

Recommendation for circular data pooling

We are data rich ….. …. but data pooling poor

Integration of underutilized public data assets with selected augmentation by private sector experts allow initial pooling

What we have learned

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We deeply care for the forest …	… while the individual trees hold the answer	**Signature products, components and materials** enable more focused analysis and overcoming BOM complexities

SOURCE: UEBS UKRI-CE-Hub

What we have learned

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We deeply care for the forest …	… while the individual trees hold the answer	**Signature products, components and materials** enable more focused analysis and overcoming BOM complexities
We tend to focus on the sunny side …	… but the dark side of the moon matters	**Linear value chains often not the issue,** Understanding the potential of circular revalorisation options (currently not yet present at scale) are the true game changers

Our joint opportunity – Circular Data pooling for improved circular ressource management
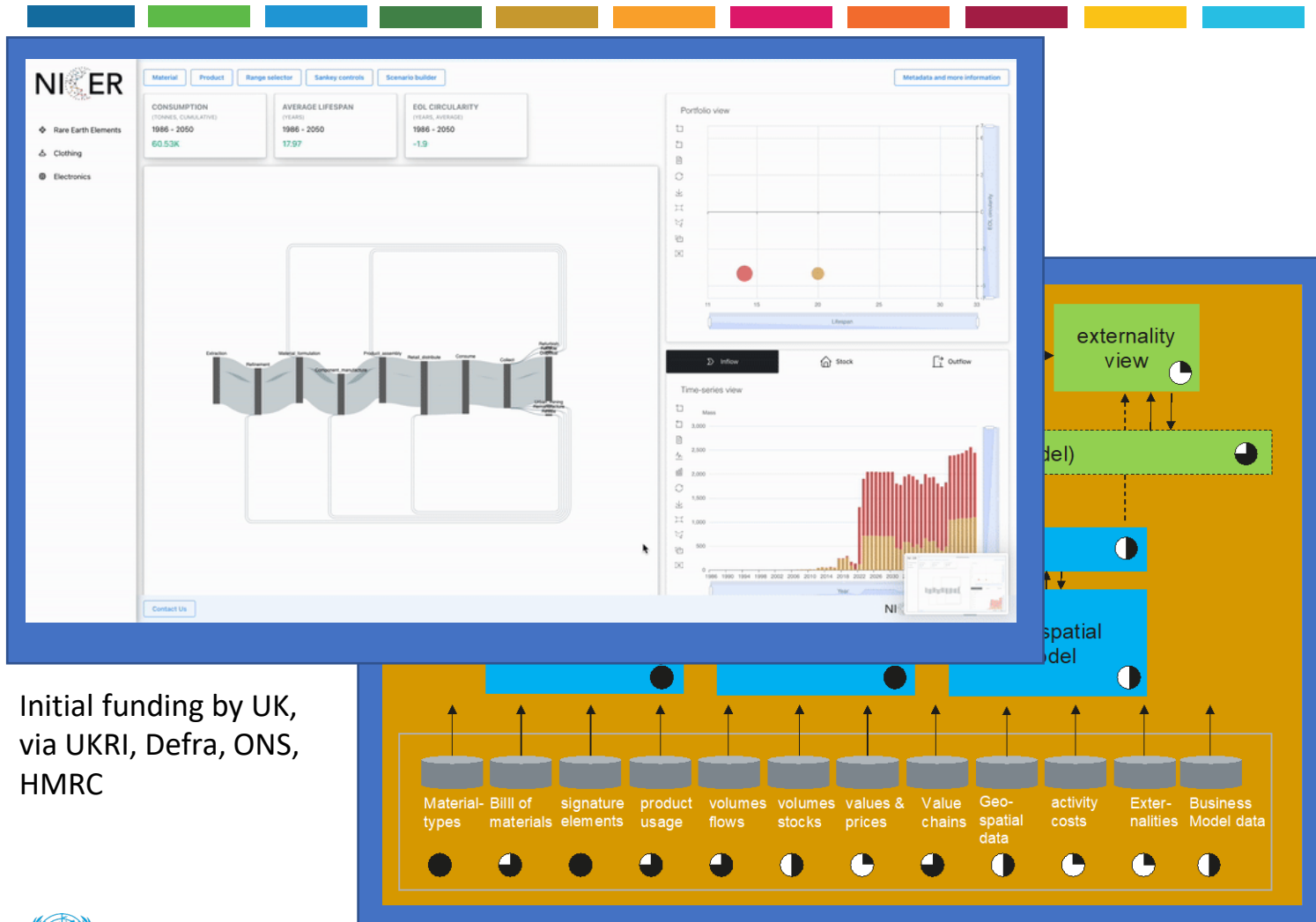
Initial funding by UK, via UKRI, Defra, ONS, HMRC

Potential of further collaboration opportunities

- **Leverage UNRMS taxonomy and definitions setting clout** to drive further standardisation for Circular Data

- **Leverage UNRMS reach and convening power** to accelerate collective, pre-competitive data pooling to scale available data across further sectors, regions and signature applications

- **Jointly collect and prioritize most important research and policy questions** to focus data pooling and circular modelling efforts
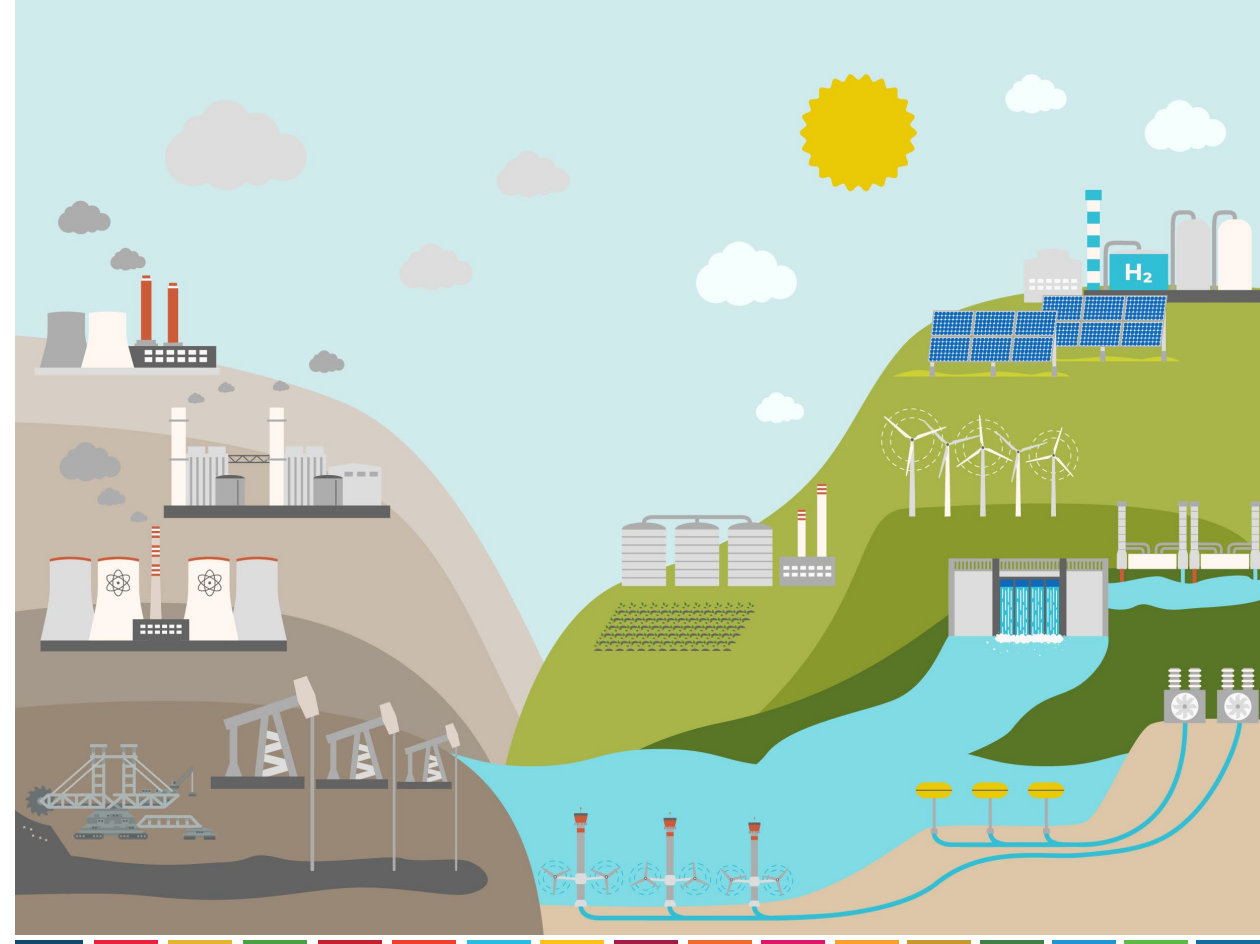
Thank you!

Prof. Dr. Markus Zils

University of Exeter Business School
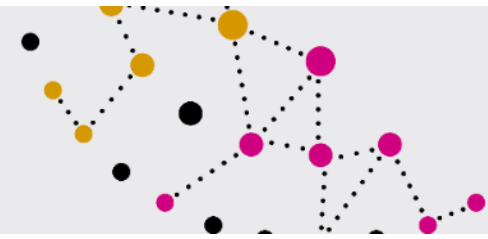
UNECE

Date 23 I 04 I 2024, Geneva

RESOURCE MANAGEMENT WEEK

2024

UNECE

Departments seek data-driven insights for effective policy making in the UK

What is the quantity and value of REE stock in the UK by 2030, 2040, 2050?

Department for Business & Trade

What products and materials do the REE end up in?

Department for Environment Food & Rural Affairs

How can we orchestrate fragmented initiatives across the REE value chain`

Ministry of Defence

How secure is our supply of mission critical equipment containing REEs?

Ministry of Defence

How big are the investment requirements vs. a projected inflow of post use REE equipment?

Industry player

Who are the key industry actors along the REE PM reverse value chain?

Department for Business & Trade

What is the contribution of the REE sector to economic growth and GVA?

Department for Business & Trade

What are current REE and REE permanent magnet recycling and recovery rates?

Department for Environment Food & Rural Affairs

What are our limits to accelerate the transition to net zero due to REE PM supply constraints?

Department for Energy Security & Net Zero

How to support cross-border trade policies to reshore REE pm manufacture and recycling in the UK?

HM Revenue & Customs

10 out of 40+ data requests collected during proof of value phase for our **REE PM signature case study** alone