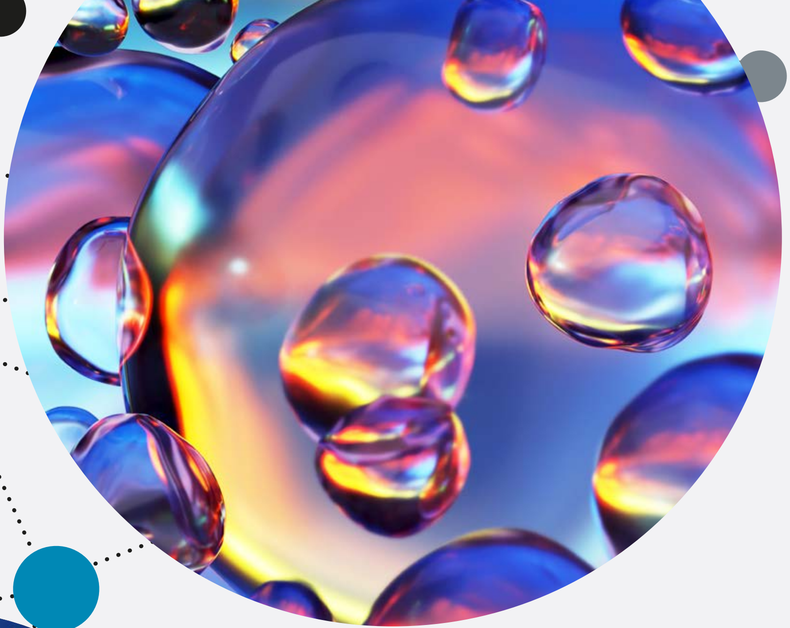


MATERIAL FLOW ANALYSIS

Insights and evidence from the NICER Programme

Rupert J. Myers [a,1], Adam R. Mason [a,2], Junyang Wang [a,3], Alperen Yayla [a,4], Tom Bide [b,5], Evi Petavratzi [b,6], Peter Hopkinson [d,7], Oliver Lysaght [d,8], Markus Zils [d,9], Alvaro Calzadilla [c,10], Teresa Domenech [c,11], Stijn van Ewijk [d,12], Julia A. Stegemann [d,13]

CE-HUB
UKRI National Interdisciplinary Circular Economy Research

NICER PROGRAMME

University of Exeter

UK Research and Innovation

Contents

a Department of Civil and Environmental Engineering, Imperial College London, London, SW7 2AZ, UK

b British Geological Survey, Nottingham, NG12 5GG, UK

c Institute for Sustainable Resources, University College London, London, WC1H 0NN, UK

d Department of Civil, Environmental & Geomatic Engineering, University College London, London, WC1E 6BT, UK

d University of Exeter Business School, The University of Exeter, Exeter, EX4 4PU, UK

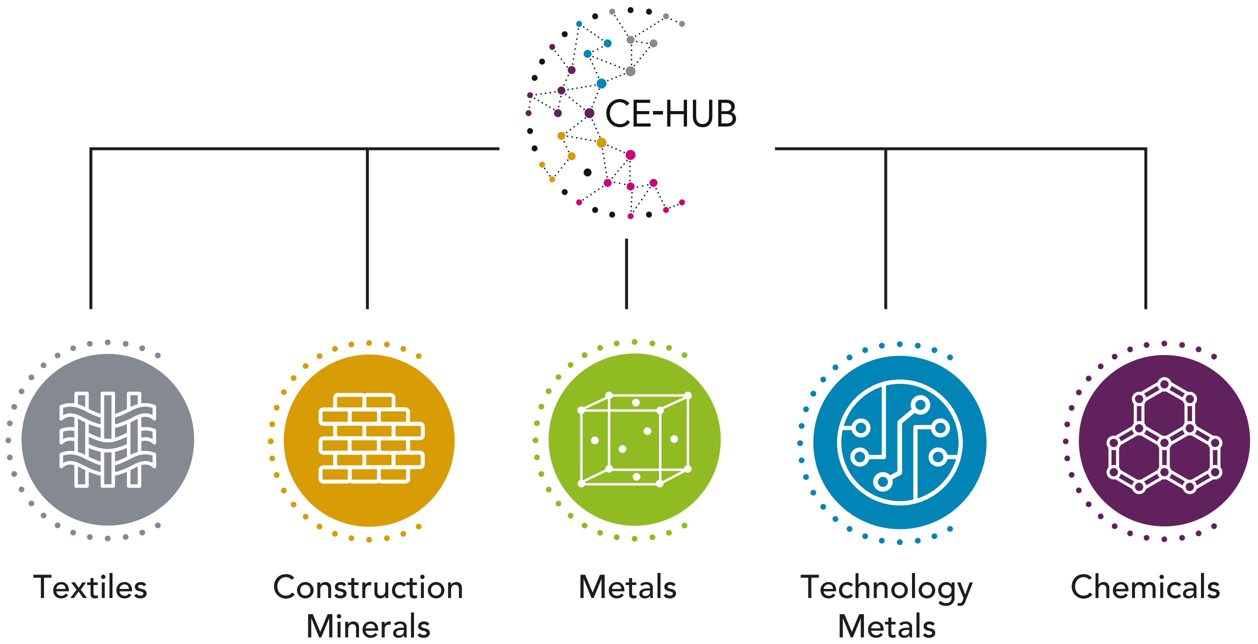
Email: 1 r.myers@imperial.ac.uk; **2** adam.rees.mason@gmail.com; **3** junyang.wang21@imperial.ac.uk; **4** a.yayla22@imperial.ac.uk; **5** tode@bgs.ac.uk; **6** evpeta@bgs.ac.uk; **7** p.hopkinson@exeter.ac.uk; **8** oliverlysaght@icloud.com; **9** m.zils@exeter.ac.uk; **10** a.calzadilla@ucl.ac.uk; **11** t.domenech@ucl.ac.uk; **12** s.vanewijk@ucl.ac.uk; **13** j.stegemann@ucl.ac.uk.

About the National Interdisciplinary Circular Economy Research Programme

The National Interdisciplinary Circular Economy Research (NICER) programme is a £30 million four-year investment from UKRI and the Department for Environment, Food & Rural Affairs (DEFRA) to deliver the research, innovation and evidence base needed to move the UK towards a circular economy. Launched in January 2021 and comprising initially of 34 universities and over 150 industrial partners, NICER is made up of five Circular Economy Research Centres each focused on a specialty material flow, and the coordinating CE-Hub:

- The National Interdisciplinary Circular Economy Research Hub (CE-Hub), led by the University of Exeter
- The Textiles Circularity Centre (TCC), led by the Royal College of Art
- The Interdisciplinary Circular Economy Centre for Mineral-based Construction Materials (ICEC-MCM), led by University College London
- The National Interdisciplinary Centre for the Circular Chemical Economy (CircularChem), led by Surrey University
- The Interdisciplinary Circular Economy Centre for Technology Metals (Met4Tech), led by the University of Exeter
- The Interdisciplinary Centre for Circular Metals (CircularMetal), led by Brunel University London.

NICER is the largest and most comprehensive research investment in the UK Circular Economy to date. It has been delivered in partnership with industrial organisations from across sectors and the Department for Environment, Food and Rural Affairs (DEFRA) to ensure research outcomes contribute to the delivery of industrial implementation and government policy. A core aim of the programme is growing the Circular Economy community through a significant programme of outreach and collaboration.



About the NICER Insight Reports series

The objectives of the NICER programme are to:

1. Accelerate understanding and solutions to enable circularity of specific resource flows,
2. Provide national leadership, coordinate and drive knowledge exchange across the programme as a whole and with policy, consumer, third sector and business stakeholders,
3. Ensure research is embedded with stakeholders by involving businesses, policymakers, consumers and society, the third sector, and other affected groups and communities at every part of the programme.

The transition towards a UK circular economy requires a whole system approach. This means that, in addition to accelerating knowledge at the resource and sector level, there are a number of agnostic system level enablers or drivers that can be applied to accelerate adoption at scale. The purpose of the NICER Insight Report Series is therefore to highlight learning from across the NICER Programme in relation to these system wide enablers.

Summary

Material flow analysis (MFA) is a method to obtain a quantitative systems overview of how we extract, use, and discard materials. It assembles data about material use from a variety of sources and applies the principle of mass conservation to quantify material flows between, and stocks within, component processes of a defined part of a material life cycle. This document summarises the principles and benefits of MFA in 9 insights, drawing on the extensive use of MFA in the National Interdisciplinary Circular Economy Research (NICER) programme.

Introduction to material flow analysis

Material flow analysis (MFA) is a well-established methodology for quantifying production and consumption of resources. It provides strategic information to improve the way materials are produced, used, and managed at end-of-use. Typical applications include identifying areas of inefficiency for practical or policy intervention; for example, in relation to any stage of the life cycle, resource efficiency, recycling rates, inputs (e.g., energy), or outputs (e.g., emissions of substances to the environment).

MFA is applicable to all sectors, and can be applied at different scales, i.e., for individual businesses, industrial sectors, and local, regional, national, and global economies. MFA can be applied over any desired period of time, for example, to understand current practice, changes over past time, or forecasting based on trends or 'what if?' scenario analysis for the future.

In relation to a circular economy, MFA can be used to help understand how virgin raw materials end up as waste at the end of their life cycles, and the potential for recovering wastes within the overall system. It can also be used as a basis for analyses of economic, environmental, and social impacts.

The first step of MFA is to define the goal and scope of the analysis, including definition of the system boundary in terms of time, space, and reference material for mass conservation. Mass conservation is the fundamental scientific principle that mass that flows into a process or system must flow out, unless it accumulates: accumulation = input – output (of mass). A system diagram that shows the system boundary and all the relevant processes, stocks, and flows pertaining to one or more materials of interest is constructed to provide a framework for mass balance calculations. Figure 1 shows a system diagram for a simple generic material system. Usually, component processes are organised left-to-right to follow the life cycle of the material(s) from extraction, through production, manufacturing, use, end-of-use, and recovery and/or disposal.

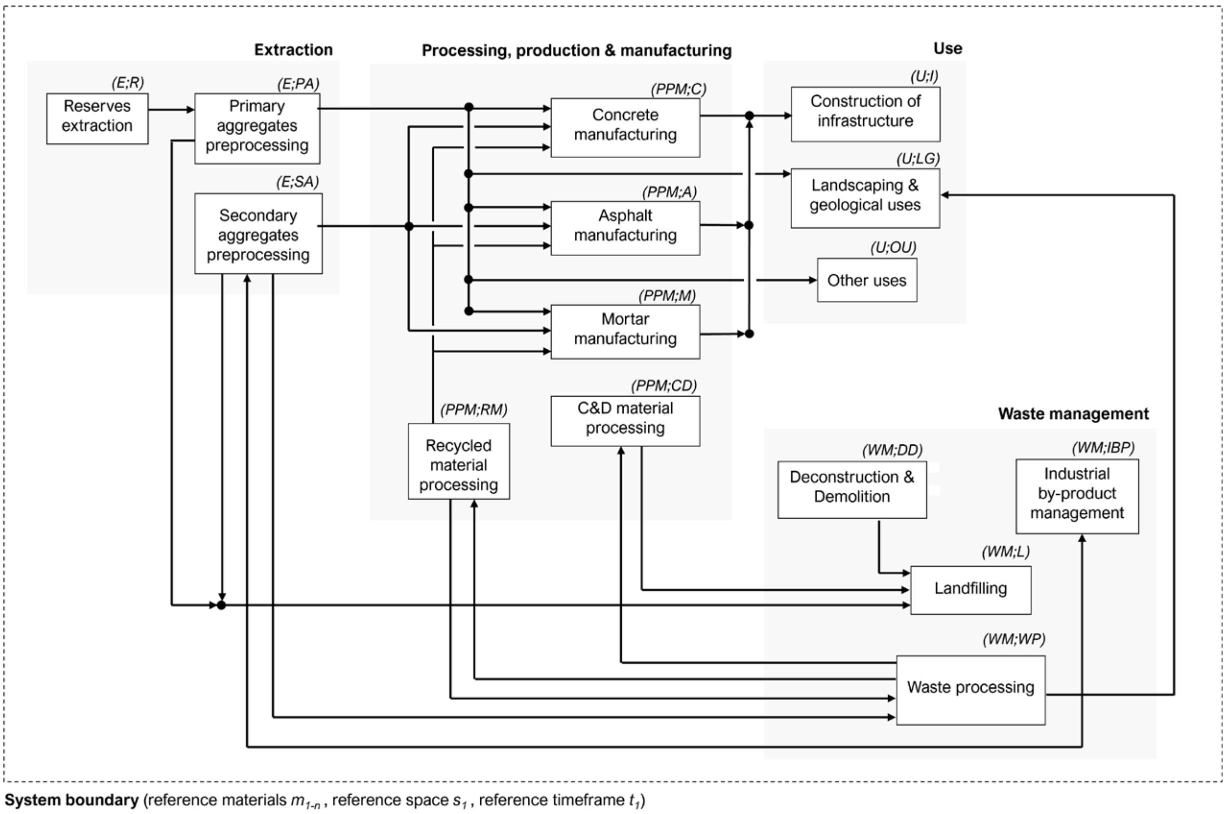


Figure 1. System diagram showing processes undergone by reference materials of interest, $m_{1\text{-}n}$, within a defined system boundary (dashed line) over a given timeframe, t_1, and region s_1. Each box (solid-line, white fill) represents a process; processes are aggregated into process stages (solid-line, shaded fill), 'Extraction', 'Processing, production & manufacturing', 'Use', and 'Waste management', that align with the system's life cycle stages. Disaggregated processes are labelled in the form, '([process stage; process])'. Each arrow represents a flow of material from process of origin to a destination process.

Once a system has been conceptualised in a system diagram, the available quantitative data for the stocks and flows of materials in the system are collected. Stock and flow data are collected from various sources, including national statistics, international trade databases, industry associations and industry. Although stock and flow data are the foundation of MFA, their availability and representation are often poor. Data are very rarely reported with adequate detail on their system contexts, and data gaps are common. Therefore, data harmonisation is essential for carrying out MFA modelling, and assumptions are often required to fill in missing information and gaps.

MFA then uses the available data to calculate the masses of all the flows and stocks in the system based on conservation of mass for each process. To aid understanding, MFA results are most often expressed visually as a Sankey diagram, in which the thickness of the arrows that represent the flows of materials between processes in the system diagram is proportional to the mass flow quantity (Figure 2).

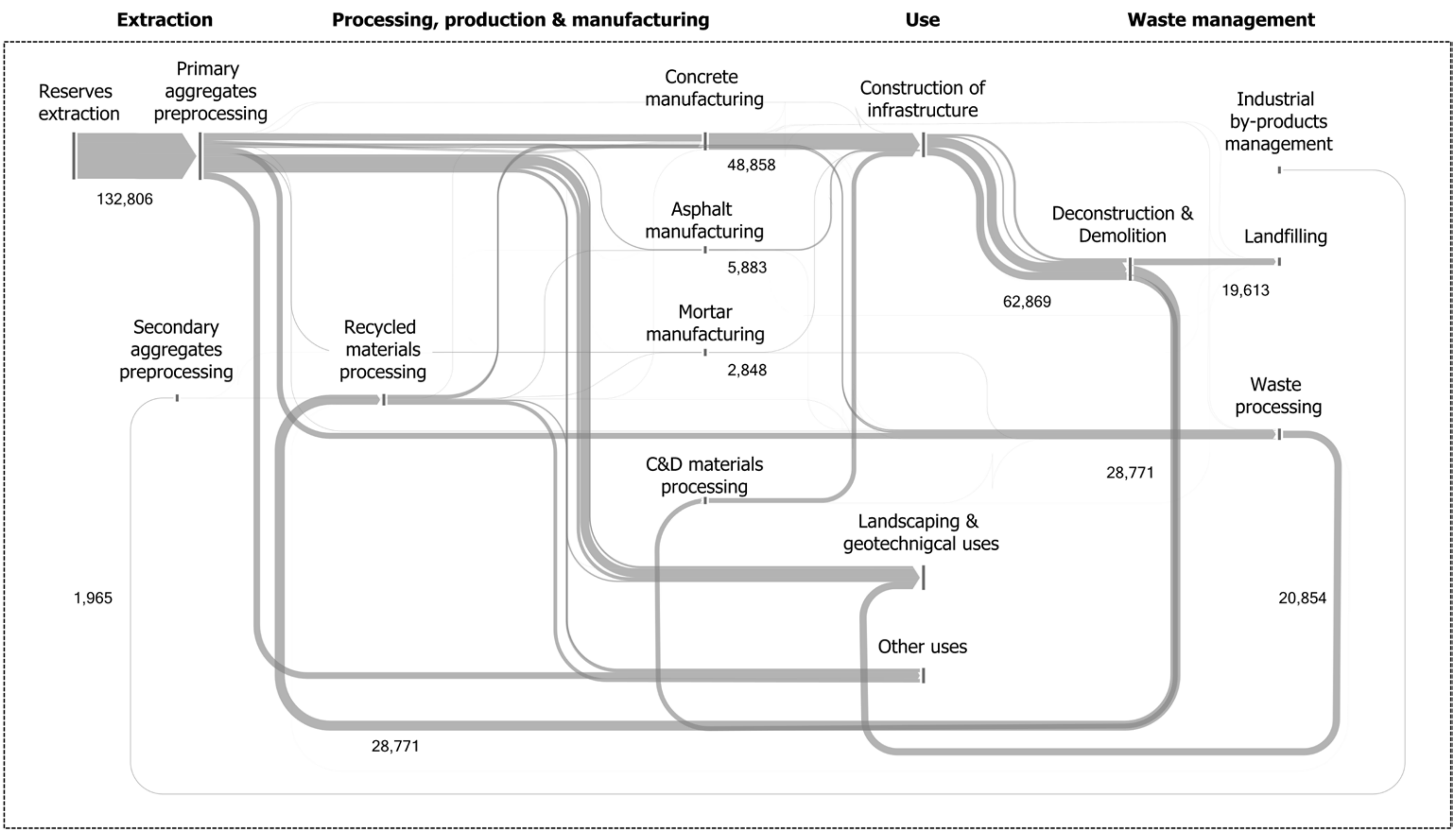


Figure 2. A Sankey diagram of the system diagram in Figure 1 showing construction aggregate (m_1) flows with arrows of thickness proportional to the flow quantity

Insights into material flow analysis

MFA is a powerful method for analysis of production and consumption, the dynamics of which are crucial for informed decision making. When used to its full potential, it can provide crucial insights for private and public sector decision-makers. Below are nine key insights about the performance and use of MFA.

1. New and surprising insights often emerge from taking a systems perspective

Material life cycles are almost always less well understood than they are assumed to be by policymakers and experts who each have experience of only a limited part of the system. A key value of MFA is its synthesis of information from various sources to quantify systems that can then be examined to gain insights across their entirety.

MFA on the basis of products (e.g., cement) can be separated into analysis of flows of important component elements (e.g., Ca) or contaminants (e.g., Cr) or combined with other material flows (e.g., aggregates), to provide insights about composite products (e.g., concrete) and systems (e.g., infrastructure, construction). Insights include understanding of the relative importance of different processes across the life cycle, constraints that control the system, and emergent properties, such as functional recycling rates, or dispersal of pollutants (e.g., toxic metals such as Pb or Cr, or organic pollutants such as nutrients, solvents, plastics, perfluoroalkyl substances), that can only be fully appreciated from system scale information.

Example: The meaning of recycling metrics

Recycling metrics drive decision-making, but what do they really mean? Various MFA studies have shown the limitations of current metrics and suggested improved metrics derived from systems analysis. Recycling metrics typically show only the fraction of discards that is collected for recycling. Such collection metrics fail to express the more systemic benefits and shortcomings of recycling. Firstly, the purpose of recycling is to displace primary production. As an example, systems analysis of paper recycling has shown that this benefit can be better captured by considering the fraction of secondary inputs to production instead of the fraction of waste recycling (van Ewijk et al., 2017). Secondly, materials are often downcycled, as shown by, for example, an analysis of municipal solid waste recycling in Switzerland (Haupt et al., 2017). Thus, the "true" recycling rate (adjusted for downcycling) is much lower than the widely used collection rate.

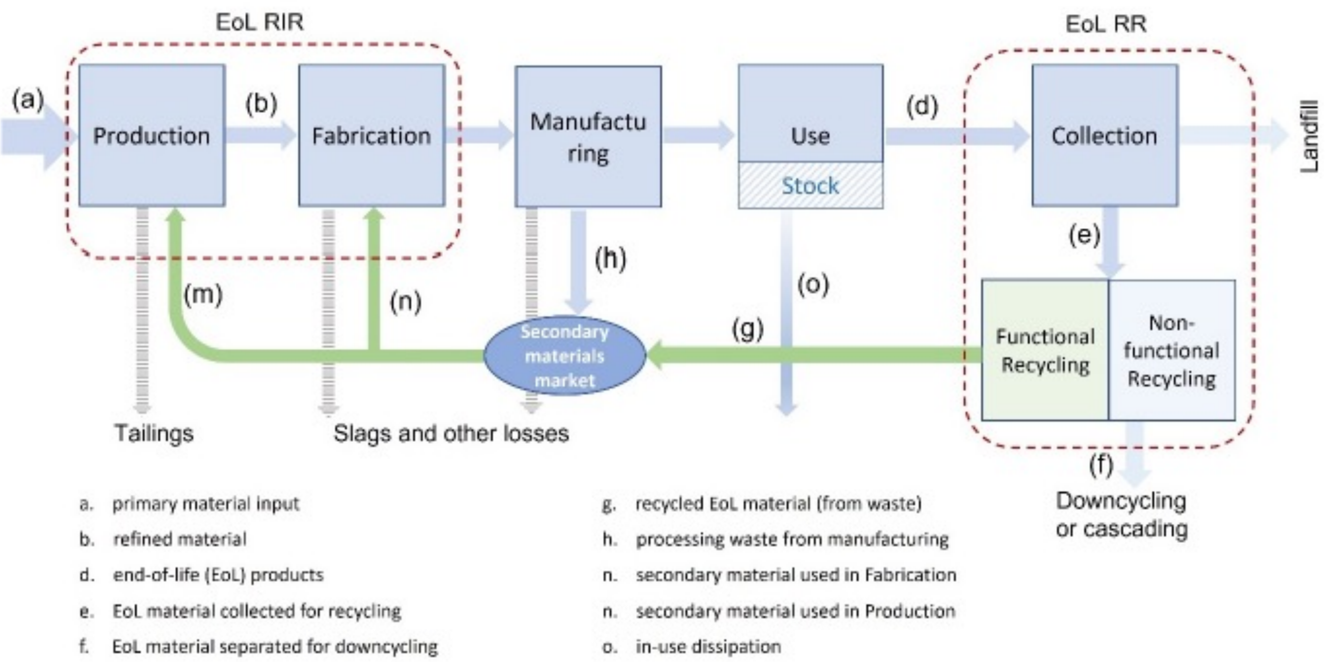


Figure 3. Value chain of the life cycle of materials outlining different recycling metrics (Josso et al., 2023).

2. Challenges in material flow analysis include data availability, compatibility, transparency, and sharing

The data used in MFA are typically compiled from a variety of public and private sources that usually did not collect the data for this purpose. The sources may be incomplete, i.e., not cover the whole system, or be out-of-date. Their different perspectives also usually result in incompatibilities and lack of transparency. For example, some sources may report sales of a material as a financial value, rather than by mass, as is needed for MFA; or sources may report only part of a multi-component flow, or aggregated information without the necessary detail of how it was determined. Some sources are reluctant to share data as they worry about the consequences for their businesses.

Lack of data availability is challenging in MFA because it means that there are typically more unknown than known stocks and flows, creating a mathematically 'undetermined' problem with an infinite number of possible solutions. This is a pervasive issue, since complete datasets are almost never available, meaning that assumptions or estimates are needed to fill data gaps.

For example, a case study was conducted by the Interdisciplinary Circular Economy Centre for Mineral-based Construction Materials (ICEC-MCM) for aggregates in the UK. Although significant effort is put into regular surveys and there are national management policies in place, most data regarding the entire system is absent or lacking in sufficient resolution, i.e., for manufacturing, use, and waste management stages. As a result, the case study required the use of proxy data from construction statistics for the use stage and estimates based on expert judgement from industry sources for waste management. These various datasets were at different resolutions (i.e., Great Britain vs England, or specific material vs building type) or from different perspectives (i.e., government statistics for house building vs industry estimates for recycled aggregates). Prior to the case study, it was assumed that data on such an important UK sector would be comprehensive. The case study highlighted how, even for comparatively common and simple flows, such as aggregates, a high degree of complexity and poor data availability can be expected. This is a common theme across most of the models developed to track different materials in the NICER programme.

Example: CE-Hub data pooling

A 2022 report published by the CE-Hub examined the availability of public data for circular economy analysis in the UK (Lysaght et al., 2022). Of over 100 data sources identified, many were potentially relevant to MFA. Nevertheless, coverage across material life cycles was found to vary and was lacking for many materials and products. No source captured information across all material life cycle stages, while barriers to connecting data included varying levels of detail and identifiers. An assessment of data 'fitness' found sources were often published with a high lag time, and showed that their findability, accessibility, interoperability, and reusability required improvement. The report made recommendations to data producers and publishers including coordinated efforts to better capture issues of relevance to the circular economy in statistical classifications, the use of controlled metadata terminology, improvements in (meta)data management, and greater methodological transparency.

3. Bayesian material flow analysis can efficiently address substantial gaps in data availability

In traditional MFA, missing values are estimated based on a qualitative understanding of the system, and trial and error estimation to fulfil the mass balance. This adhoc process is laborious and the estimates are hard to rigorously justify. An alternative approach is provided by Bayesian material flow analysis (BaMFA). BaMFA is an emerging advanced MFA methodology that uses Bayesian statistics to estimate unavailable data and overcome the undetermined nature of MFA problems. It combines quantitative observed (previously measured or reported) data with semi-quantitative information provided by experts and uses Bayes' Theorem and mass conservation to estimate the stocks and flows in the most likely system.

BaMFA also calculates the uncertainty associated with its estimates of stocks and flows. This is a significant advantage over conventional adhoc data reconciliation, which cannot rigorously quantify the uncertainty associated with assumptions used to fill data gaps. Understanding the uncertainty surrounding stock and flow estimates is an important consideration for strategic decision-making. By identifying areas of the material system where uncertainty is highest, BaMFA can also help target data collection strategies to reduce overall uncertainty.

Compared with adhoc data reconciliation, BaMFA is generally a low cost method once the model is adjusted for a particular system. It can be rapidly updated with new data, for example, when more data for other parts of the system become available, or for a new time period. It can help perform MFA with limited public data sources, requiring few demands of detailed, potentially "commercially sensitive", information about industrial activities. The rapid nature of the method is important since some systems change quickly, new data is becoming available all the time, especially with the development of modern automated data collection techniques, and policy questions that require forecasting for new scenarios can change quickly.

Example: Bayesian material flow analysis methodology

The ICEC-MCM has developed BaMFA methodology (Wang et al., 2024) that allows disaggregated flows and processes to be modelled through a new parent child process framework. The methodology improves upon computational stability and scalability compared to existing methods, allowing Bayesian MFA to be applied to larger and more variable MFA systems. In addition, the methodology identifies the changes-in-stocks and flows with the largest uncertainty, and employs Bayesian posterior predictive checking to help identify inconsistencies in the data. This improves data collection practices by prioritising the collection of more reliable data to describe and model material systems.

The BaMFA methodology (Wang et al., 2022) has been applied to quantify the construction aggregate system for England in 2019 (Mason et al., under review) and global wood cycles (Yayla et al., under review). These studies have been able to quantify the aggregate and wood systems to a higher level of detail than through conventional MFA methods, in particular waste management flows and change in stock values of construction products in current use.

4. Universal classification of materials and activities can improve data transparency, sharing, and utility

Various classification systems exist today to describe products (e.g., Harmonised System [HS]), wastes (e.g., European list of waste codes [LoW or EWC]), and activities (e.g. Standard Industry Classification [SIC]). They are generally a good starting point for quantifying stocks and flows in material systems using MFA. However, these classification systems do not adequately describe the different components and substances that may comprise a product, including secondary materials. This is a fundamental challenge for MFA to support a circular economy, since product composition influences how products are manufactured and can be recycled. Classification systems may also not provide adequate descriptions of the system contexts of their products and activities. Therefore, there is a need to further develop and harmonise existing classification systems to enable more detailed breakdown of product flows into components and substances in a standardised way, and provide more complete information regarding their systems contexts.

Given that several industrial classification systems exist, it would be useful to develop a unifying 'super classification' system to harmonise existing classification systems, for consistent application across data collection and MFA of different material systems – at least to define aggregated economic sectors or industrial activities to achieve a basic level of consistency across MFA studies. However, developing a super classification system is challenging because different classifications systems disaggregate processes and products differently, causing mismatching that cannot always be reconciled (Myers et al., 2019a; Myers et al., 2019b). This is especially true for data in the scientific literature, which is created on an ad hoc basis specific to individual studies. There is a research need to understand how mismatched literature data can be more efficiently integrated into future MFA studies.

Example: NICER Data Observatory

This topic is especially relevant in data pooling and the work done by the NICER CE-Hub and Centres on the Data Observatory. The Data Observatory is intended as a repository for data on material flows and stocks in the UK, linked to economic and impact dimensions. It is populated from a range of sources, including research across the NICER programme, official data and industry reports. It is designed to incorporate updates as these become available to support monitoring, while also storing and presenting (meta)data with a basic level of consistency to aid comparison and prioritisation. Alongside a baseline picture, the Data Observatory facilitates the integration of diverse models for exploring scenarios with circular economy interventions and policies applied. It is being further developed through the 2024-25 Defra Fellowship Programme to tailor it as a policy decision-support tool.

5. Material stock and flow models support more extensive analysis of social, environmental, and economic impacts

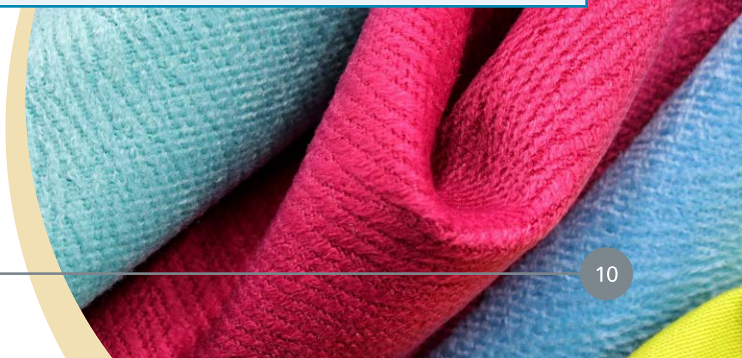
Physical units of mass are the basis of MFA, since the analysis is based on conservation of mass; this expression also makes the results of MFA physically meaningful. Once the mass flows are established, MFA can also be used as a basis for other analyses, such as tracking changes in financial value as a material moves between economic actors and through the system, or life cycle assessment (LCA) of environmental and social impacts (Josa et al., 2024). MFA thus gives a consistent framework for evaluating the physical, economic (cost-benefit and proof-of-value analysis), environmental, and social impacts of implementing circular economy policies and practices.

Many datasets (e.g., UN Comtrade) report both mass and monetary values (as well as physical units of traded goods). This allows systems to be defined in terms of both these units, although completeness and accuracy across these variables can vary (Jiang et al., 2022). Combining measures of physical units with value can help to examine resource efficiency and also changes of value along the value chain, including for recovery at end-of-use. For example, iron ore is transformed to steel and then to manufactured products and to scrap; during this material transformation value is added and then lost (and captured by individual actors/sectors), which can be identified by multiplying the physical quantity of the materials along the supply chain with their corresponding costs and prices. Therefore, MFA can indirectly highlight areas where value is generated, appropriated, and destroyed.

A particularly important and common use of MFA is as a basis for the calculation of environmental and/or social impacts across the stages of a material flow system or product life cycle, such as greenhouse gas (GHG) emissions and pollutants, impacts on biodiversity, (ecosystem health), or employment. For example, van Ewijk et al. (2021) estimate material flows associated with the global pulp and paper sector, as well as the GHG emissions associated with each stage of the life cycle, from forestry to end-of-life disposal. The results show that recycling can reduce the demand for forest product, but also that increased recycling does not necessarily reduce the climate impacts because of the widespread use of fossil fuels in the recycling process.

Example: Material flows and carbon footprint of fashion textiles in London

The Textiles Circularity Centre (TCC) combined MFA with LCA and scenario modelling to assess the material flows and carbon footprints of textiles, and the current degree of circularity of the system. The scope of the work covered the full life cycle of fashion items consumed by Londoners, including extraction of fibres to management of postconsumer waste. The combined MFA-LCA methodology was also used to quantify the potential effects of 'circular strategies' in terms of resource savings, waste generation, and greenhouse gas emissions reduction. The study found that every year Londoners acquire 154,600 tonnes of new clothes, or around 48 garments each, creating over 2 million tonnes of greenhouse gas emissions. It also found that reducing primary consumption of clothing and promoting second hand markets can reduce greenhouse gas emissions by over 30%, as much as 40% of postconsumer clothing was sent to landfill or incineration, and that a large fraction of postconsumer clothes collected from households was exported to third countries. Most of these impacts were associated with clothing imports, which represent 92% of clothing sold in London, and are responsible for 87% of the total greenhouse gas emissions produced by London's clothing supply chain.



6. Material flow analysis supports scenario comparisons, analysis of historical trends and future projections, and forecasting

Static MFA results, i.e., for a system at a single time point (e.g., a 'snapshot' of a recent year), are useful to understand a material system, and model scenarios of the impacts of interventions in the system over the short term. "Short term" may be surprisingly long, as technologies often take years to evolve and businesses need to collect returns on their investments in existing facilities, so many supply chains and material systems change only over decades. This means that process efficiencies and system diagrams are approximately constant within those timescales. Short term scenario modelling is important since current environmental targets require rapid systemic change. 'Snapshot' modelling is routinely applied in answering other complex and prospective questions, such as strategic assessment of critical minerals flows (e.g., the European Commission publishes critical raw material lists every three years; European Commission, 2024).

Dynamic MFA uses historic trends to forecast future stocks and flows in more rapidly changing systems and over the longer term. The impacts of known, planned or potential changes or interventions to the system can be explored using scenario modelling.

Example: Tracing current and future flows and stocks of rare earth elements in the United Kingdom

The CE-Hub and Met4Tech utilised both historic data and future demand scenarios based on policy commitments (for electric vehicles and wind energy) to estimate the total quantities and material value of rare earth elements in rare earth permanent magnets in the UK economy through to 2050 (Hsu et al., 2024). The static model provides a detailed view of the permanent magnet rare earth flows across the whole UK value chain over a period of five years (2017 to 2021). It identifies the UK dependencies on global markets and provides the underpinning data for future scenario development. The dynamic forward-looking stock-flow model pooled multiple public datasets and developed a bespoke activity classification since rare earth element products are absent in UK standard industrial classification (SIC) codes. The forward-look model estimates the stocks of rare earth elements and permanent magnets in end-of-life electric vehicles and wind turbines (up to 2050) and has developed a range of scenarios to identify circularity interventions.

7. Data availability is better for extraction and consumption than for waste generation and management

In most cases, availability of information is worse for processes that are further downstream. Mining to production stages tend to be well monitored and recorded (e.g., via trade protocols, codes). Increasing complexity of the system for materials in-use and after end-of-use leads to data scarcity. Assumptions and estimates are therefore needed to model downstream processes of a material system, leading to greater uncertainty than for upstream processes. In particular, wastes are reported in categories that are generally uninformative about the nature of the material being discarded, and often in highly mixed and aggregated form (Sander et al., 2008). This is a significant limitation for analysis of the circular economy, which depends on an accurate understanding of the availability of high-quality materials as secondary materials after end-of-use. In general, stocks are not reported, and can only be estimated.

In the built environment, stocks are being estimated based on geospatial information about building footprints collected by satellite, use of different materials in buildings (i.e., their material intensities, in units of mass per area), and flows at end-of-use based on estimated building lifetimes. However, estimates of building lifetimes (e.g., those used in the national capital accounts; Rincon-Aznar et al., 2017) are both inaccurate and imprecise, and records of demolition waste are generally poor (Cao et al., 2017). Although voluntary measures are being advanced to fill these gaps (European Decontamination Unit, 2017), our understanding of the potential for recovery of secondary materials from demolition is still inadequate.

Example: Unavailability of data for construction aggregates

In the ICEC-MCM MFA study of construction aggregates (Mason et al., under review), we found extraction/reserves, sales/import, and export data to be better described than use phase data. Whilst there is excellent data coverage for the production of aggregates from a comprehensive government survey (Mankelow et al., 2021), data around aggregate use and waste management stages (whether recycling or disposal) are almost entirely lacking and required either proxy datasets or assumptions from industry experts. This is in part due to the difficulties around monitoring waste management. For construction, waste management is spread across multiple sectors, building sites, and infrastructure projects at a variety of scales. Construction and demolition waste is often re-used in downcycled form within individual projects and these flows are not usually reported. Quarries also produce large amounts of material, e.g., from earth moving operations, and including by-products from industrial processing, such as crushing, that will never leave the site and remain unrecorded despite being significant flows of raw materials.

8. The location of material stocks and flows is important because of local resource availability and transport distances

Both transport infrastructure and operation of all forms of transport have major economic, environmental, and social impacts. Secondary materials, which often have a low price relative to their transport costs, have a high 'place value' (Walport et al., 2017). Knowledge of the geospatial distribution of stocks and flows is therefore important for sustainable material supply in general, and in developing circular value chains. For example, location affects the scope for recovery (e.g. refurbishment, repair, recycling) of materials that are highly sensitive to the associated costs and environmental impacts of involved transport and for which scale economies for more widely distributed stocks do not apply. Large volumes of common materials are usually not transported far, e.g., construction and demolition waste, whereas smaller quantities of high value materials can be traded internationally, e.g., cobalt. The need to connect sources and sinks of activities within circular value chains means that their implementation needs to satisfy criteria for geographical location (e.g., acceptable cost, impacts and logistics), as well as quality (e.g., substance composition) and quantity (e.g., available amounts). These are therefore all key aspects of MFA scenario analysis.

Example: NICER Data Observatory plastics stock-flow model

The CE-Hub produced an MFA of annual post-use plastics flows within three regional counties in Southwest England and their end of life pathways (closed recycling, open loop recycling, incineration, landfill, export, and loss to environment). Data sources on the collection, sorting, and segregation of different waste streams (farming, fishing, household, commercial) spans multiple infrastructure, locations and public and industry contracts. Distances from points of collection to recovery or disposal sites were previously poorly mapped and required building a geographic information system model to measure distances between points that have a significant effect on carbon footprint calculations. An initial MFA study was able to show the tonnages of plastics flows leaving the system by over 20 different polymer types, and the material value and embedded carbon as a basis for identifying opportunities for circular economy interventions. This model is being scaled up for the whole of England and Wales through a Defra fellowship recruited from the NICER Centre for Circular Chemical Economy (CircularChem).

9. Material flow analysis can be used to quantify the circularity of a system and guide policy action

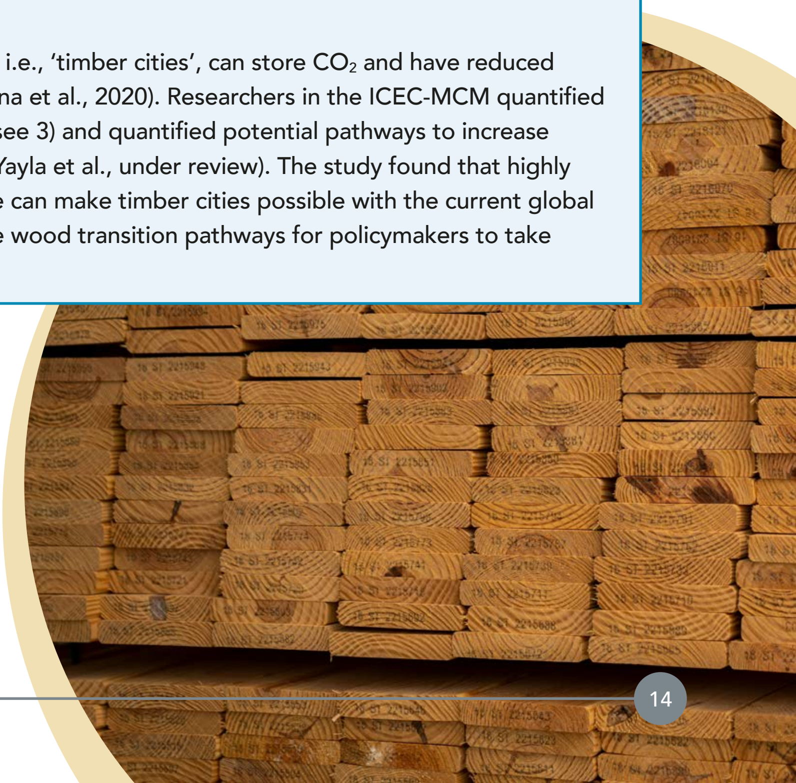
The circular economy concept aims to reduce the amount of resources used per unit of service obtained (i.e., improve resource service-efficiency), using systemic insights and changes. MFA is an ideal methodology to provide the systemic quantitative evidence to achieve this aim. For example, understanding of the dynamics of primary extraction, additions to the in-use stock, ability of materials and products to remain in the stock, and the rate at which they become waste are all key aspects of both MFA and assessment of resource service-efficiency. Moreover, MFA is essential for reliable generation of data needed to calculate circular economy metrics, including absolute production and consumption quantities, rates of cyclical use (e.g., reuse, open or closed loop recycling), rates of material lost (e.g., to incineration and landfill), and composite indicators that combine physical data with social or economic data, such as resource productivity.

MFA can also be used to identify a range of policy challenges and solutions, including the following:

- The inefficient uses of materials along value chains, and the intervention points to address that inefficiency. A full systemic analysis can show at which stages in the material life cycle most of the material is unnecessarily lost. For example, studies have shown the share of food waste lost in different parts of the chain, including farming, processing, retail, and consumption (Shepon et al., 2022).
- The potential systemic consequences of policies targeting material flows. For example, a simple analysis can show the benefits of source separation on the recovery rate of a specific wastes, but a full systemic analysis can also show the indirect effects on facilities that used to receive the same waste in the past, and the implication for capacity requirements and treatment costs and revenues.
- More comprehensive cost-benefit analysis to estimate the impacts of circular economy interventions across full material cycles, rather than standard cost-benefit analysis that considers only a part of the system.

Example: Identifying pathways towards large-scale wood transition to timber cities

Cities with new buildings constructed mostly using wood, i.e., ‘timber cities’, can store CO_2 and have reduced carbon footprints compared to conventional ones (Churkina et al., 2020). Researchers in the ICEC-MCM quantified the current state of the global wood cycle using BaMFA (see 3) and quantified potential pathways to increase engineered timber production and achieve timber cities (Yayla et al., under review). The study found that highly circular use of wood or shifting wood fuel to industrial use can make timber cities possible with the current global harvesting volume. Wood MFA, therefore, reveals feasible wood transition pathways for policymakers to take action globally and regionally.



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