

## **Understanding the socioeconomic implications of resource emergencies and associated mitigation policies using Bayesian material flow analysis**

Supervisor (primary): Dr. Rupert J. Myers, Department of Civil and Environmental Engineering

Supervisors (co): Dr. Pablo Brito-Parada, Department of Earth Science and Engineering; Dr. Yves Plancherel, Department of Earth Science and Engineering; Dr. Kolyan Ray, Department of Mathematics.

### **Background:**

Demand for materials and energy are increasing. Decarbonisation ambitions such as the Paris Agreement imply a radical longer-term shift from fossil materials utilisation (e.g. fuels for energy, feedstock for chemicals) to minerals (e.g. metals for renewable energy technologies) and biomass (e.g. bio-derived chemicals). Shorter-term shifts in resource flows can also have huge socioeconomic implications, such as the UK 'energy crisis' (2022). However, the socioeconomic impacts of these issues, which often arise from significant supply-demand mismatches, remain poorly understood. Hence, there is a growing and urgent need to systemically quantify and analyse how resources are used in the economy, to discover sustainable production-usage patterns that avoid supply-demand mismatches in the shorter and longer terms. This information then needs to be disseminated to policymakers, industry, and the resource community, so the necessary systemic actions can be taken to mitigate undesirable impacts.

Previous research by Myers and colleagues on this topic, funded by the UKRI Circular Economy Centre in Mineral-Based Construction Materials [1], the Office for National Statistics, and as part of the Imperial-X Resources Observatory (RO) [2], has developed the Bayesian material flow analysis methodology needed for a quantitative digital twin of the physical economy [3]. This research involves comprehensive mapping of resource stocks and flows from extraction through to end-of-life, and then application of this systemic quantitative evidence to inform policymaking and business strategy. The vision for its application is to focus on resource emergencies and black swan events (UK energy crisis, semiconductor chip shortage, trade partner import/export bans such as the Rare Earth Crisis [4], etc.), to better understand these and to both propose mitigating policies and understand their efficacy – much like COVID-19 epidemiological modelling in SAGES [5], which showed effects of individual measures like social distancing on COVID-19 infections/mortality and demand for health services [6].

This approach was initially demonstrated by its application to understand the supply/demand balance of construction aggregates in England until 2030. We are now seeking to enhance its capability by applying it to other material systems and important current resource issues.

### **Project description:**

This PhD project will focus on improving the capability of Bayesian material flow analysis methodology to model stocks and flows of materials as a function of time ('dynamically'). Practically this is done on a yearly basis using time series data. This will include application of statistics and scientific programming in our existing Python code.

The improved methodology and code will be applied to analyse the supply/demand balance of critical materials. This will include the major critical material producers (and corresponding processing steps), fabricators, manufacturers, users, and what happens to the materials at end of life.

This will require the following objectives to be met:

1. Development of datasets describing the material and energy compositions of products and production/waste treatment/recycling process inputs and outputs
2. Improvement of our Python code (on our Imperial-hosted github repository) so it can ingest both material and energy data, and splice its outputs by region (e.g. UK), material cycle, and product (or product category, e.g. permanent magnets).
3. We expect that these advancements will be demonstrated by modelling different competing technology options within the same product category, e.g. different materials for defense products, to understand their resource implications. Dissemination of these research outcomes to key stakeholders such as policymakers will also be key.

### **Who we are looking for:**

The PhD student working on this project will be joining the interdisciplinary IROB team which contains several academics, postdocs, and PhD/MSc/UG students, as well as collaborators at the BGS and UCL. We are passionate about science and sustainability, enjoy working with one another, and meet fortnightly. We are seeking a student who shares similar values and would enjoy this vibrant research environment; is ambitious, inquisitive, creative, and independent; and will thrive at the exciting and fast-moving cutting edge of sustainability science, in one of the world's top universities and locations for this area of research.

The start date of the position is flexible.

### **Applicant requirements:**

1. First class degree (or international equivalent) in engineering or science or a closely related subject, ideally including mathematics (statistics) and programming, e.g.: Mathematics, Quantitative Economics, Physics, Computer Science, Chemistry, Chemical Engineering, Environmental Science.
2. Strong interest in sustainability and research.
3. Excellent English communication skills.

### **How to apply**

Applicants wishing to be considered for this opportunity should send the following application documents to Dr. Rupert J. Myers ([r.myers@imperial.ac.uk](mailto:r.myers@imperial.ac.uk)):

1. Current CV including degree result and, if possible, class ranking

Application via the Imperial College Registry is not necessary at this stage.

Applications will be regularly reviewed until the position is filled.

### **Funding notes**

Applicants interested in this project and seeking funding via scholarship schemes (see here: <https://www.imperial.ac.uk/study/pg/fees-and-funding/scholarships/>) or can self fund are welcome to apply.

### **References:**

1. CE-HUB: UKRI National Interdisciplinary Circular Economy Research. Centre for Mineral-Based Construction Materials. Accessible at: <https://ce-hub.org/centre-for-mineral-based-construction-materials/>
2. Imperial College London. Imperial-X – Human and Machine Learning. Accessible at: <https://www.imperial.ac.uk/imperialx>
3. Wang, J.; Ray, K.; Brito-Parada, P.; Plancherel, Y.; Bide, T.; Mankelow, J.; Morley, J.; Stegemann, J.; Myers, R.J. *ArXiv*, A Bayesian approach for the modelling of material stocks and flows with incomplete data. <https://doi.org/10.48550/arXiv.2211.06178>
4. Mancheri, N.A. *Resources Policy*, 46(2), 262-271, (2015). <https://doi.org/10.1016/j.resourpol.2015.10.009>
5. UK Government. Scientific Advisory Group for Emergencies. Accessible at: <https://www.gov.uk/government/organisations/scientific-advisory-group-for-emergencies>
6. Ferguson, N.M. et al., Report 9: Impact of non-pharmaceutical interventions (NPIs) to reduce COVID-19 mortality and healthcare demand. Accessible at: <https://www.imperial.ac.uk/media/imperial-college/medicine/mrc-gida/2020-03-16-COVID19-Report-9.pdf>