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# EPiC: Introducing a database of hybrid environmental flow coefficients for construction materials

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**Abstract.** As worldwide consumption of materials continues to rise, there is growing pressure on material, energy and water resources and an increase in waste production and greenhouse gas emissions. A much more sustainable approach to the procurement of built assets is crucial to avoid exacerbating existing environmental pressures. Product and process-based environmental data is an important element in understanding how current and future built assets perform. This paper analyses environmental flow data for a range of construction materials contained within the Environmental Performance in Construction (EPiC) Database, a new, open access repository of hybrid environmental flow coefficients for construction materials. The structural paths of 131 construction materials are analysed to identify trends and contributors to embodied water, energy and greenhouse gas (GHG) emissions coefficients. The disaggregation and analysis of material coefficients shows the complexity of the material supply chains and provides insight into the key inputs and outputs resulting from the production of construction materials.

## 1. Introduction

As the world struggles to remain within a rise of 1.5°C from pre-industrial levels, buildings and infrastructure continue to place a considerable burden on the natural environment. This is expected to be exacerbated by rising populations and economic growth. In 2018, buildings accounted for 36% of total global final energy use and nearly 40% of energy-related CO<sub>2</sub> emissions [1]. In response to these challenges, the 2018 IPCC Special Report on Climate Change and Land (SRCCCL) is calling for broad transformations to the building sector, with a rapid phase out of CO<sub>2</sub> emissions [2].

Life cycle assessment (LCA) is a widely accepted tool used to quantify the environmental effects of buildings. By quantifying effects, efficiencies can be identified, leading to improved environmental performance of buildings, urban projects and infrastructure. Conducting detailed LCAs can be time intensive and costly, relying on complex analyses of material supply chains and processes [3]. To streamline LCA calculations, life cycle inventories (LCI) in the form of environmental flow coefficients are often used, allowing for the rapid quantification of environmental flows across the life cycle of a built asset. Environmental flow coefficients provide a simple quantitative measure of environmental flows associated with particular construction materials and can include indicators such as energy use, water use, land use, waste production and greenhouse gas emissions.

This study examines the Environmental Performance in Construction (EPiC) Database, a new open access LCI repository of hybrid embodied environmental flow coefficients for construction materials. There are 284 coefficients contained within the database (of which 131 are assessed here), compiled



using a Path Exchange hybrid approach, predominantly using Australian bottom-up process data and top-down macroeconomic input-output data [4].

Although various other LCIs and similar databases exist, they often suffer from inconsistencies in system boundaries, lack of data transparency and variations in temporal and geographical specificity. There are three approaches commonly used to compile environmental flow coefficients, these include: process analysis, environmentally-extended input-output analysis (EEIO) and hybrid analysis.

Process analysis includes a detailed analysis of manufacturing processes in order to develop an inventory of resource inputs, and outputs of waste and emissions. It typically has a high degree of reliability, however can suffer from inconsistencies in system boundaries, which can vary considerably depending on the quality and depth of available data. EEIO analysis uses macroeconomic data combined with national environmental data to quantify the environmental flows between industry sectors. This typically covers the entire economy and enables an almost complete system coverage, but this approach is limited in its specificity to particular products or processes. Hybrid analysis combines process analysis and EEIO analysis; taking advantage of the reliability of process analysis and the increased system coverage of EEIO analysis [5].

### *1.1. Aim and scope*

The aim of this study was to explore the system boundaries, limitations, and complexity of the supply chains of the materials contained within the EPiC Database. This provides insight into the inputs and outputs resulting from the production of construction materials, illustrating how analyses of structural paths can be used to identify and potentially prioritise improvement efforts for resource or emissions intensive processes.

## **2. Research method**

This study examines the structural paths of 131 construction materials contained within the EPiC Database across three environmental flows: energy, greenhouse gas (GHG) emissions and water. 153 materials have been excluded from this study, as they represent minor variations to the primary materials. All data used for analysis is available as open access datasets via Figshare [4].

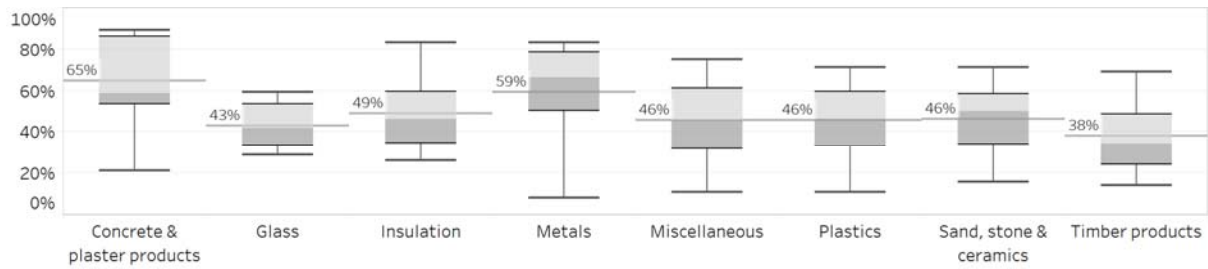
The compilation of hybrid coefficients is based on two structural path analyses (SPA) [6]; the first conducted on the 114 sectors contained within an Australian EEIO model for 2014-15 and the second conducted on process data representative of each material from the AusLCI shadow database [7, 8]. These structural path analyses vary in coverage from 38%-99% of the flows for each material or sector, with an average of 78% coverage for EEIO data and 90% for process data across all environmental flows. In total, there are 145,541,274 individual data points (nodes) included in the SPAs, with each node representing a separate material or sector input or process. There is on average more than 1 million nodes per material, with process nodes representing 12% of the total nodes. The outputs of these SPAs are used to analyse the EPiC coefficients. More information on the method used to conduct the SPAs can be found in [9] and the code can be freely downloaded from <https://github.com/hybridlca/pyspa>.

## **3. Analysis of EPiC coefficients**

This section describes the preliminary analysis of the SPA results for the selected EPiC coefficients.

### *3.1. System boundaries*

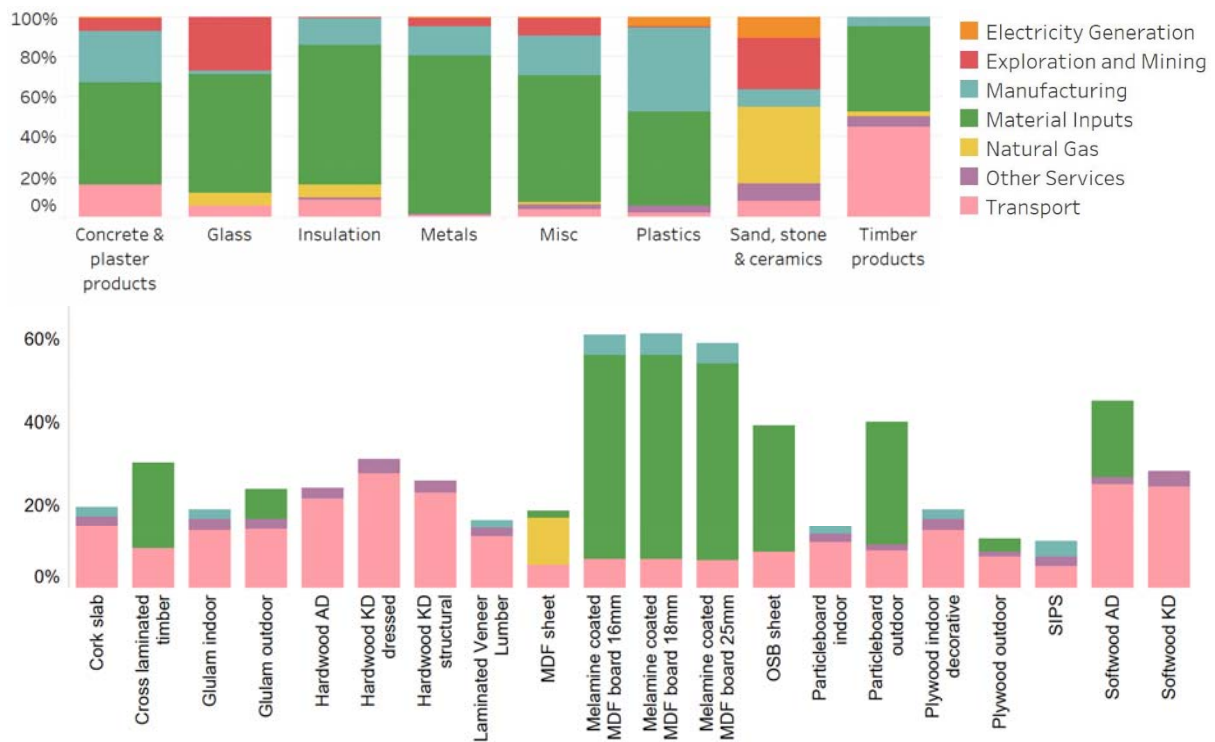
During the hybridisation of material coefficients, gaps in process data are supplemented with EEIO data; prioritising process data where it is available, while leveraging the extended system boundaries of EEIO data. This ensures that all coefficients have comparable system boundaries, enabling more reliable comparison between coefficients [3]. In the EPiC Database, the percentage of process data that makes up the final hybrid coefficients varies significantly; for greenhouse gas emissions it ranges from 8% to 89% as a percentage of the final coefficient, with an average contribution of 51% (Figure 1).



**Figure 1.** Contribution of process data to GHG emissions coefficients in the EPiC Database.

**3.2. Top contributors to embodied greenhouse gas emissions**

The top three stage one (direct) inputs of GHG emissions have been extracted for each of the 131 materials analysed. These are grouped into seven categories and displayed as a contribution to the total top three stage one inputs for each material category (Figure 2). Further disaggregation at a material level provides additional insight into the top contributors of GHG emissions for each material (Figure 2). The data demonstrates the significance of material inputs across all categories except one.



**Figure 2.** Contribution of the top three stage 1 inputs to GHG emissions, by material category (top), and for timber products (bottom).

**4. Discussion and conclusion**

On average, over 1 million individual nodes were used to calculate environmental flow coefficients for each of the 131 unique materials contained within the EPiC Database, demonstrating the complexity of the material supply chains. An additional 153 materials are available in the database, representing different functional units and variations of the primary materials.

The contribution of process data used in the compilation of hybrid coefficients varies widely (from 8% to 89% in the case of GHG emission flows). This indicates a significant variation in the

completeness of process data. Where detailed process data is available, such as for many concrete and plaster products, this is reflected by a higher contribution of process data (Figure 1). Timber has a lower contribution from process data in part due to the high contribution of transport, which has been calculated using EEIO data in the EPiC Database due to the limited completeness and representativeness of transport-related process data.

Examination of structural paths allows the identification of top contributing processes to environmental flows. In this instance, the contribution of specific processes to GHG emissions provides insight into areas of possible GHG emissions reduction. Although more detailed analysis is outside the scope of this study, Figure 2 shows the significant contribution that transport makes towards the GHG emissions associated with the production of timber products. Further disaggregation illustrates that transport contributes over 20% of the total GHG emissions for ‘hardwood’ and ‘softwood’ and a significant proportion for all timber products.

This study illustrates how an analysis of structural paths of material LCI data can provide insight into the top contributors of environmental flows. Meaningful conclusions on specific contributions will require additional analysis outside the scope of this study. This is easily achievable as data transparency throughout the EPiC Database allows for a high degree of analysis, with open access datasets available via Figshare. Due to the location specific and temporal nature of the coefficients, this analysis is most relevant to the Australian context. However, due to the global nature of material supply markets, the knowledge gained from this and further analysis of the EPiC coefficients remains highly relevant for many other economies and contexts. This information can be used by policy makers, industry and built environment specialists to identify possible efficiencies and improve the environmental performance of materials, products and construction projects. This will help in our attempts to create sustainable cities (SDG11) and ensure the sustainable consumption of materials and other resources (SDG12) into the future.

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