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The greenhouse gas emissions and mitigation options for materials used in UK construction: Supporting Information

The following supporting information contains:

1. Basic description of UK MRIO Model used to establish embodied emissions
2. Additions to the model results
3. Allocation of emissions by activity
4. Literature used to ascertain barriers to alternative materials, technologies and practices

1. Basic description of UK MRIO Model used to establish embodied emissions

The model used to estimate embodied emissions associated with the construction sector is an updated version of the UK MRIO model developed at the University of Leeds for DEFRA [1]. The model is a multi-region Environmentally Extended Input-Output model structured around data from the UK's Office of National Statistics (ONS) with trade data sourced from the Eora model [2], developed at the University of Sydney. Four regions are considered: the UK, the rest of the EU, China and Rest of the World (ROW). Supply, Domestic Use and Domestic Final demand tables from ONS at 106 sectors (based around Standard Industrial Classifications) make up the domestic section of the model. UK imports to intermediate demand are also available from ONS by sector, but the data on the source sectors and regions supplying these imports is not. Using the UK sector totals as a constraint, the intermediate flows are distributed using proportions from Eora. The final demand of UK consumers for imported goods is also calculated using Eora proportions and UK product total constraints. A similar method is used to proportion exports from UK industry to foreign intermediate and final demand. Finally, Eora supplies trade between the rest of the EU, the rest of the world and China and their final demand to complete the model.

The National Accounts produced by the ONS provide Greenhouse Gas Emissions totals by the 106 UK sectors. Emissions for foreign sectors are taken from Eora. Data in Eora is not supplied at the 106 sector classification used by the UK. Instead, Eora uses a heterogeneous sector classification that reflects the original input-output data submitted by individual national statistics agencies. Each of the sectors reported by the 185 regions[1] in Eora are mapped to the UK's 106 sector classification. For some cases sectors are aggregated to map to UK sectors, however often Eora sectors have to be disaggregated to two or more UK sectors. Sector disaggregation calculations use the UK's total output as a weight.

The UK MRIO model used in this analysis differs slightly to the model used to calculate the UK consumption based accounts for Defra. The model used here ensures that spend representing UK final demand for an imported product is constrained by product proportional spends observed in the UK's national accounts. The Eora model is then used to proportion spends by import region. The Defra model takes total final demand spend on all imported products and uses proportions from Eora to calculate by product and region.

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[1] The 186 Eora regions minus the United Kingdom

2. Additions to the model results

Additional figures have been added to the construction sector total to correct for an accounting anomaly whereby transactions made directly between material producers and households do not appear within the influence of the construction sector. A short explanation of this correction follows.

The core model is built on detailed data covering financial transactions within different sectors of the economy. If a householder purchases materials directly from producers, then this purchase will not fall within the influence of the construction sector. For certain materials this can lead to significant omissions. For example, whether purchased through the construction industry or bought directly, cement is solely used for construction purposes. Therefore a true estimate of the total embodied impacts of all construction activities must include these transactions. A correction was thus devised to account for the emissions from material producers that are directly supplying household final demand. The COICOP classification of household expenditure by purpose, developed by the United Nations Statistics Division, was used to estimate levels of household final demand that corresponded to direct expenditure on construction materials. This was done by computing the proportion of total household expenditure by product category under classification '04.3 Maintenance and repair of the dwelling'. Proportions were established for each year across the following product categories: 'wood and products of wood and cork, except furniture; articles of straw and plaiting materials'; 'paper and paper products'; 'paints, varnishes and similar coatings, printing ink and mastics', 'rubber and plastic products', 'manufacture of cement, lime, plaster and articles of concrete, cement and plaster', 'glass, refractory, clay, other porcelain and ceramic, stone and abrasive products', 'other basic metals and casting', and 'fabricated metal products'. These proportions were then used to redistribute errant material production emissions to construction. This results in a correction of 4.93 $MtCO_2e$ (~9% of total embodied emissions) in the average year. These figures were computed for each year from 1997-2010. The figure for 2011 was based upon the proportion from 2010 as the ONS implemented fundamental changes to their methodology to comply with ESA95 for their 2013 release which presented the 2011 figures [3]. This new classification method effectively excludes all expenditure on repair and maintenance from owner-occupiers and is thus no longer suitable for this purpose.

3. Allocation of emissions by activity

Figure 2 representing the breakdown of emissions by activity was produced by the following means. The total emissions attributable to the construction sector in the UK MRIO model were broken down by source sector. Totals for the four principle activities were then assembled by addition of relevant sector sub-totals. The share of emissions from electricity attributable to construction activities was established from a basic first step decomposition. It was assumed that the remainder of emissions from electricity were attributable to 'materials extraction, manufacturing and production'. This is likely a slight overestimate as some of the emissions from electricity will be attributable to 'Other' activities. However, this share is likely very small as energy-intensive material production processes (such as the manufacture of aluminium) are likely to dominate. Even if total emissions from electricity are split proportionally among

non-construction activities then the total attributable to materials would still exceed 45% in a typical year. The table below details the model sectors included in each activity.

Materials extraction, manufacturing and production	Construction Activities	Transport of people, plant and materials	Other
Other mining and quarrying products	Direct emissions from construction	Rail transport services	All other classifications
Wood and of products of wood and cork, except furniture; articles of straw and plaiting materials	Waste collection, treatment and disposal services; materials recovery services	Land transport services and transport services via pipelines, excluding rail transport	
Paper and paper products	Rental and leasing services	Water transport services	
Coke and refined petroleum products	Share of emissions from electricity attributable to construction activities	Air transport services	
Paints, varnishes and similar coatings, printing ink and mastics			
Petrochemicals			
Rubber and plastic products			
Manufacture of cement, lime, plaster and articles of concrete, cement and plaster			
Glass, refractory, clay, other porcelain and ceramic, stone and abrasive products			
Basic iron and steel			
Other basic metals and casting			
Fabricated metal products, excl. machinery and equipment and weapons & ammunition			
Electrical equipment			
Emissions from electricity not attributable to construction activities			

4. Literature used to ascertain barriers to alternative materials, technologies and practices

Evidence of barriers to uptake was gathered from a literature search of academic publications, supplemented by publications from trade bodies and other non-academic sources. The initial literature search was based upon 115 search terms entered within Science Direct, Compendex, Inspec and Google Scholar. This returned 5264 results from which 1154 publications were extracted. Further evidence was added from 'citation trails' and from consulting the work of relevant institutions in each field. This high volume of results was filtered by applying an approach similar to that adopted by UKERC in their Technology and Policy Assessment Reports [4]. All pieces of evidence were assigned a relevance rating as outlined in the table below. Detailed attention was paid to those documents of high relevance (rated 1 or 2), with limited consideration of evidence rated 3 or 4. By this process an understanding of each alternative was garnered and the common barriers to uptake tabulated.

Relevance Rating	Description of Evidence
1	Evidence clearly deals with one or more key aspects of research questions
2	Evidence is relevant but presented in a way that could preclude direct comparison with other results
3	Evidence is of limited relevance
4	Evidence deemed not of relevance upon closer inspection

References

[1]   T. Wiedmann, R. Wood, M. Lenzen, J. C. Minx, D. Guan, and J. Barrett, "Development of an Embedded Carbon Emissions Indicator - Producing a Time Series of Input-Output Tables and Embedded Carbon Dioxide Emissions for the UK by Using a MRIO Data Optimisation System," Report to the UK Department for Environment, Food and Rural Affairs by Stockholm Environment Institute at the University of York and Centre for Integrated Sustainability Analysis at the University of Sydney, DEFRA, London, 2008.

[2]   M. Lenzen, K. Kanemoto, D. Moran, and A. Geschke, "Mapping the structure of the world economy.," *Environmental Science & Technology*, vol. 46, no. 15, pp. 8374–81, Aug. 2012.

[3]   ONS, "Blue Book 2013: Improvements to Household Expenditure Estimates," 2013. [Online]. Available: http://www.ons.gov.uk/ons/rel/consumer-trends/consumer-trends/q1-2013/blue-book-2013--improvements-to-household-expenditure-estimates.html#tab-Improvements-to-sources-and-methods. [Accessed: 10-Dec-2013].

[4]   UKERC, "TPA Overview," 2012. [Online]. Available: http://www.ukerc.ac.uk/support/tiki-index.php?page=TPA Overview. [Accessed: 12-Dec-2012].