The role of consumption in material reduction opportunities: the impact of product lifetime in supplying the UK steel demand

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Abstract: Most of the products purchased in the UK are manufactured in other countries. As a result, worldwide greenhouse gases (GHG) emissions released to manufacture all products purchased in the UK are significantly higher than the UK territorial emissions. More than one half of global industrial emissions result from the use of steel, cement, paper, plastics, and aluminium. In this paper, the UK consumption of products that embody these five materials is estimated. For steel, which is the most widely used among these five materials, consumption and accumulation patterns are examined across four product categories. The impact of steel product lifetime extension is examined for the UK as one option for material demand reduction at the consumption stage of the supply chain. Different levels of steel product lifetimes are simulated for the UK in 2050 and their impacts are examined in terms of UK steel production, implicit steel imports, and global carbon dioxide emissions. Steel product lifetime extension promotes a reduction in the need for steel imports, by reducing the demand for new steel, which leads to lower carbon dioxide emissions required to supply the UK steel demand. The results demonstrate the criticality of a focus on the consumption stage, since any interventions made towards demand reduction of end-use goods leads to material reduction across the supply chain.

Introduction

In 2007 around 715 Mt of carbon dioxide equivalent were emitted in the UK, as a result of human activities, including industries, transport, electricity generation, and direct household emissions. However, to produce and deliver all goods and services purchased in the UK, around 1 Gt of carbon dioxide emissions have been released worldwide in the same year (HM Government, 2013).

The UK Government is committed to a reduction of 80% of 1990 GHG emissions by 2050 (HM Government, 2011). Such policy targets rely only on GHG emitted within each country's borders, so ignoring the fact that in many developed countries (such as the UK) the emissions associated to purchases are significantly higher than territorial emissions (Hertwich et al., 2009). Since these developed countries are currently the only held to emissions reduction targets, a focus only on territorial emissions may foster industries to be offshored to countries that do not have such targets and therefore not addressing the global problem of carbon emissions.

The magnitude of GHG emissions for which UK purchasing is responsible for highlights the relevance of potential emissions savings resulting from material reduction opportunities in delivering the UK products purchased by UK consumers.

More than a half of worldwide industrial emissions result from the use of only five key materials: steel (which alone accounted for 25% of worldwide industrial emissions in 2005), cement (19%), paper (4%), plastics (4%), and aluminium (3%) (Allwood et al., 2012). These materials are widely used to manufacture products, which are purchased and used worldwide. Any interventions across the supply chain of these materials – from resources to manufactured products – aiming to reducing material use have the potential to deliver significant energy and emissions savings.
Material efficiency opportunities can be identified at any stage of the supply chain of

these materials. Normally, such opportunities are grouped according to the stage of the supply chain where interventions are sought: (i) production, comprising the primary and manufacturing industries; (ii) business-to-business transactions, aiming material reduction at intermediate products, providing the same output of end-use manufactured products; (iii) consumption, aiming material reduction of final purchasing, yet providing the same levels of service delivered to the final user.

In this paper the role of material reduction options at the consumption stage of end-use products is examined, focusing on the impacts of product lifetime extension. We start by quantifying the impact of UK consumption in terms of GHG emissions and material use. From the five key materials listed above, steel is the most widely used in the UK. We therefore examine the use of steel in the UK at the consumption stage of the supply chain, quantifying its uses by product category. The impact of changes in steel product lifetimes in meeting future UK climate targets is analysed.

UK material use and emissions: focus on steel

Manufactured products purchased annually in the UK comprise around 20 Mt of steel, 12 Mt of paper, 11 Mt of cement, 5 Mt of plastics, and 1 Mt of aluminium. Figure to Figure show how these five materials are embodied in different product categories purchased in the UK. Vehicles, buildings and infrastructure are among the products that require the highest shares of several of these materials. Steel is by far the most used material of these five and its use in the UK is examined here in further details.

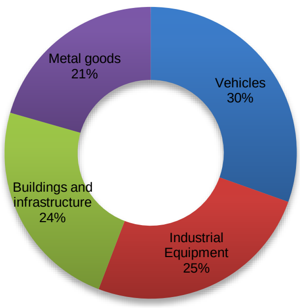

Figure 1. Steel purchased in the UK by product category. Source: ISSB, 2008.

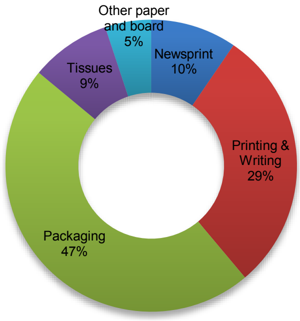

Figure 2. Paper purchased in the UK by product category. Source: CEPI, 2013.

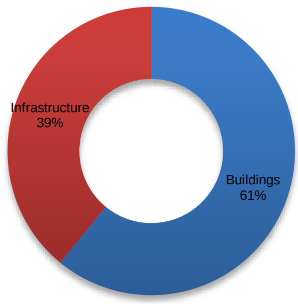

Figure 3. Cement purchased in the UK by product category. Source: CSI, 2011.

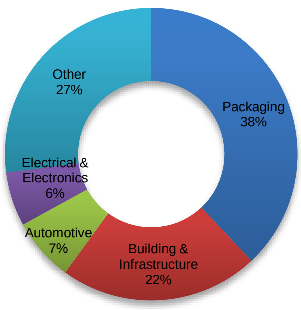

Figure 4. Plastics purchased in the UK by product category. Source: British Plastics Federation, 2014.

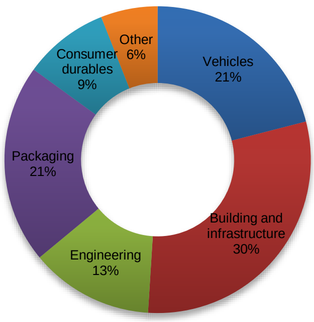

Figure 5. Aluminium purchased in the UK by product category. Source: Dahlström et al., 2004.

Over the last 40 years, 15 Mt of new steel were annually purchased in the UK. UK steel purchases have become increasingly more dependent on imports. Figure shows that the quantity of steel produced in the UK that is subsequently delivered to the UK market has been decreasing and accounting for decreasing shares of the total UK demand.

Crude steel is the first solid stage of steel in a steel mill and the primary output of the most energy - and carbon-intensive iron - and steel - making processes. Crude steel is then subject to further downstream processes at the steel mill where around 6% of it is lost, some of which is recovered as process scrap. Later in the supply chain, when steel products are used to manufacture final goods, on average 19% of steel is lost to fabrication scrap. Therefore to provide the annual average of 15 Mt of steel purchased in the UK, steel industries in the UK and elsewhere need to produce a greater quantity of crude steel to overcome an average of 25% of yield losses across the supply chain. The blue bars in Figure show these figures.

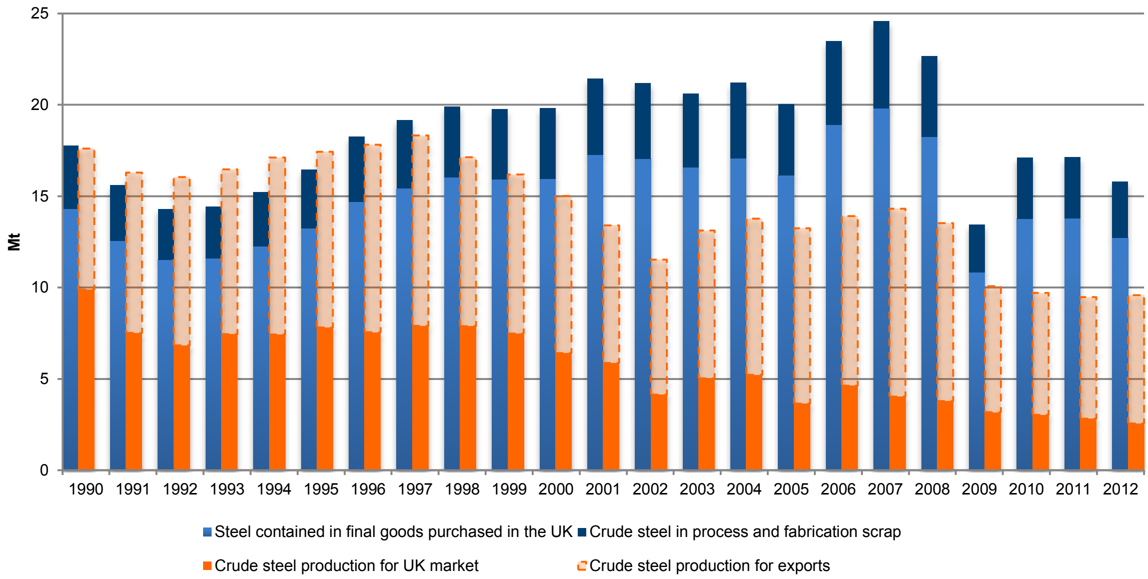

Figure 6. UK steel production and consumption, 1990 – 2012. Blue bars show steel and crude steel required to supply UK consumption. Orange bars show steel production in the UK. Source: ISSB (2008) and authors' calculations.

Current flows and stocks of steel in the UK

In 2007 around 20 Mt of steel was embodied in purchased products in the UK, and only around 13 Mt of end-of-life steel scrap was discarded and removed from use (Dahlström et al., 2006; ISSB, 2008; authors' calculations). This trend has been verified for many years, although with different magnitudes, but on average each year, new steel purchased in the UK exceeds the end-of-life steel discarded. As a result, the stock of steel in use in the UK has been increasing every year. Pauliuk et al. (2013b) have estimated the current in-use stocks of steel for 200 countries, including the UK. Figure shows an estimation of the in-use stock of steel in the UK, as of 2007. Most of the steel currently in use is in buildings and infrastructure, since these products are made using large quantities of steel, their use is pervasive, and they usually last for longer than other product categories.

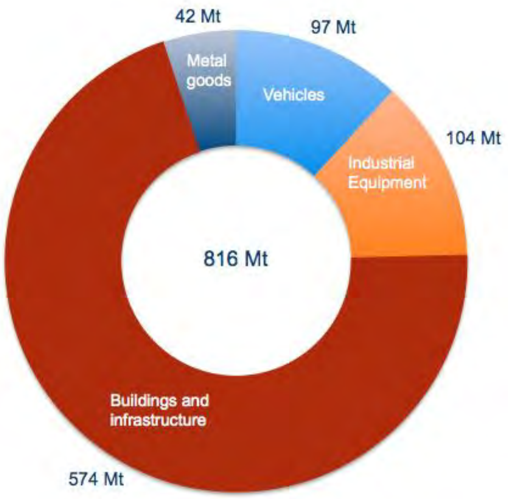

Figure 7. Estimated in-use stock of steel in the UK, 2007. Source: Adapted from Pauliuk et al., 2013b.

In 2007 the in-use stock growth rate was different for each product category. Figure 8 shows an estimate of steel added to the in-use stock and end-of-life steel scrap removed by product category. 63% of steel consumed by buildings and infrastructure was a net addition to the in-use stock in the UK, since 4.7 Mt of new steel were used in this product category and only 1.7 Mt removed as end-of-life scrap from existing buildings and infrastructure. Around 40% of the steel in the UK consumption of vehicles and metal goods was a net addition to the in-use stock of those product categories. However, new steel in industrial equipment almost matched end-of-life steel scrap arising from this product category.

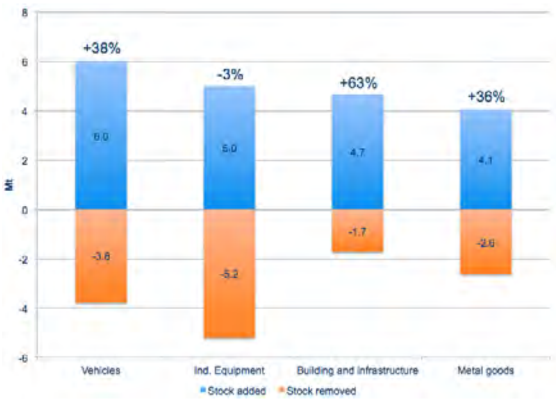

Figure 8. Estimated net additions to the in-use stock of steel in the UK, 2007.

The impact of product lifetimes in meeting future UK climate targets

Pauliuk et al. (2013a) estimate that the in-use stock of steel should reach a saturation level by 2030 at around 13 tonnes per capita in Western European countries. Assuming such stock saturation by the time current UK carbon targets must be fulfilled, the UK steel consumption in 2050 would only be required to maintain the existing in-use stock. Further replacing equal amounts of end-of-life scrap that occur each year, plus new stock required by population growth. Table 1 shows the saturation stock and average steel product lifetimes estimated by Pauliuk et al. (2013a). Under such conditions, and taking into account the population growth rate projected by the ONS (2013), the UK demand for crude steel in 2050 is estimated to be around 32 Mt.

To achieve the emissions reduction commitment, the UK Government has developed the Carbon Plan, setting how the UK should make a transition to a low carbon economy and developing pathways for the structure of the UK energy sector and the energy uses across the different industrial sectors (HM Government, 2011). Each pathway defines the final energy uses by industrial sector and thus their GHG emissions, so the overall impact for the UK would be to meet the target of 80% reduction from 1990 emissions.

Product categories	**Saturation stock [tonnes per capita]**	**Average lifetime [years]**
Vehicles	1.3	20
Industrial equipment	0.9	30
Buildings and infrastructure	10.0	75
Metal goods	0.6	15
Total	12.8	

Table 1. Estimated saturated in-use stock of steel and product lifetime. Source: Pauliuk et al., 2013a.

For example, in one pathway of the Carbon Plan (created by the cost-optimisation model MARKAL) (HM Government, 2011), it is estimated that the UK steel industry would be allowed to emit 10 Mt of CO_2 in 2050. Under this scenario, with the current structure of the UK steel industry, it would be possible to produce around 5.5 Mt of crude steel, which is far below the total estimated UK demand (32 Mt). As a result, the minimum amount of crude steel implicit in imports would be 26.5 Mt.

Importing steel either in the form of finished steel products (e.g. sheets, bars, coils) or in the form of manufactured products (e.g. vehicles, equipment) results in significant impacts and carbon emissions due to sea borne transport of heavy shipments (Yellishetty et al., 2010). Furthermore, crude steel production in other countries to supply UK demand for imports also entails carbon emissions related to UK consumption, which are estimated to be around 1.1 t CO_2 / t crude steel in 2050 (Allwood et al., 2010).

Graphs in Figure show the impact of changes in steel product lifetimes from those assumed in

 in UK crude steel production, the required implicit crude steel imports, and worldwide carbon dioxide emissions to supply the UK steel demand. Three alternatives are assessed: extending average lifetimes for all product categories of

 by 20%, by 50%, or decreasing by 20%.

Product lifetime extension may be achieved by fostering reuse and repair of existing products in-use or even by reducing the need of material services. The estimate presented here shows that extending steel products lifetime in 50% can save around 10 Mt CO2 worldwide comparing to the baseline scenario, can decrease the need for steel imports, and can support UK employment in the maintenance and repair industries.

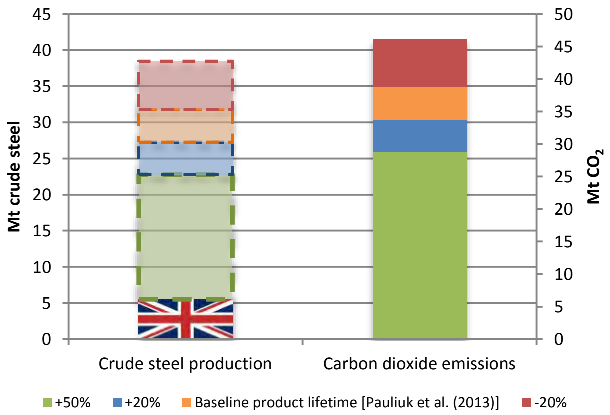

Figure 9. Estimated crude steel production in the UK in 2050, implicit crude steel imports (dashed lines), and worldwide CO_2 emissions for different levels of steel product lifetimes in the UK.

Conclusions

The impact of steel product lifetime extension is twofold: (i) longer product lifetimes result in a reduction of pace of replacement of existing saturated stock, and thus reducing the total UK steel demand and consequently the implicit imports required; (ii) producing smaller annual quantities of steel requires less energy uses and consequently smaller carbon dioxide emissions (both in the UK and in other countries to supply the UK steel demand).

Maintenance of in-use stocks and the reduction of the pace at which they are replaced by new flows of material result in a reduction of the impacts associated to material production. Our results show that steel products lifetime extension can deliver significant global emissions savings as a consequence of decreasing the demand for steel imports.

This example on the impacts of steel products lifetime extension in the UK shows the criticality of a focus on consumption. In the steel industry significant progress is possible either at the production stage (such as process yield improvements) or at the business-to-business transactions (such as improvements of fabrication yields and efficiency of manufacturing processes), although material reduction options at the consumption stage have impacts across the entire supply chain. Material reduction opportunities at the consumption level lead to a reduction in demand for all primary materials used to manufacture end-use products. This shows a particular relevance in the case of steel, whose use is pervasive in the UK and whose production stages are the most energy-intensive processes of material conversion.

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