



Liberty House Group response to the National Assembly's Economy, Infrastructure and Skills Committee consultation on the future of the steel industry in Wales.

About Liberty House

Liberty House Group is an international business specialising in metals trading and the manufacture and distribution of steel and advanced engineering products. Operating from four hubs in London, Dubai, Singapore and Hong Kong, the Group has sites in Europe, Africa, the Middle East, the Far East, Australia and North America. With a network of offices spread across 30 countries around the world, its current turnover is about \$4.3 billion and it employs around 3,000 people globally – including currently 250 in South Wales. Liberty is focused on promoting GREENSTEEL; a sustainable, balanced international business that is non-cyclical, environmentally conscious and socially responsible, and has an integrated and agile business model. The Group has a strong, established business with a deep knowledge of the global steel sector, developed over the last quarter of a century. Over recent years it has developed a track record of investing in the UK steel and engineering industries and securing jobs in these sectors. Liberty House Group is a member of the GFG Alliance, an association of businesses owned by Parduman K Gupta and Sanjeev K Gupta.

The Alliance's key focus is the creation of a resilient, integrated supply chain – ranging from liquid steel production based on recycled scrap and powered by renewable energy, to steel and highly-engineered products manufactured locally on a global basis, funded through a pioneering financial approach. In 2016 GFG's combined turnover totalled US \$6.7bn with net assets are valued at US \$1bn. The GFG Alliance comprises of four distinct businesses: Liberty Commodities Group (LCG) a comprehensive services provider to the global steel and metal industries; Liberty Industries Group (LIG), an integrated steel producer and distributor of steel and advanced engineering products; SIMEC, an international resources group focused on sustainable power, mining, shipping and infrastructure assets; and GFG Investments an innovative financial services and properties platform.

Consultation Summary

Our vision for the future of steel in Wales, and the revival and growth of the industries that steel supports, is all built around our GREENSTEEL vision. GREENSTEEL is steel used in the UK produced in the UK – and from raw materials sourced from the UK. The UK currently imports 80% of our steel and steel products. We also export more scrap steel per head than any other country and this is then sold back to us by those countries as imported raw or semi-finished steel or steel-based end products. We want to change this and create new opportunities for job creation at home by recycling UK scrap and using renewable energy to manufacture steel at a competitive cost and with a smaller Carbon footprint

We strongly believe that, unless the UK and specifically Wales adopts a new and more competitive business model for steel then we will see the continued decline and eventual demise of this pivotal industry. We base our vision and strategy on what we have seen work successfully in the USA and elsewhere overseas, and would like to work with the National Assembly for Wales and Welsh Government to help facilitate the creation of a new vision for steel production which will help it both survive and flourish.

We would recommend the committee read Professor Julien Allwood's paper "a bright future for UK steel" and also the Metals Processing Institutes (MPI) paper "Electric Steelmaking: The New Paradigm for UK Steel Manufacture" both attached.

Q1. What do you think of the work to date of the Steel Task Force?

Groups like the Steel Task Force provide vital help in identifying ways to address some specific challenges facing the sector. The task force has highlighted challenges such as high energy costs and business rates and unsupportive procurement practices that have a negative impact on UK steel companies today.

We also see a role though for a body that takes a more holistic view of the steel industry in Wales and sees where National Assembly and Welsh Government support can help the industry and those it supports to flourish. Groups that focus on resolving day-to-day issues are vital but, without overarching strategy and vision, we fear that the industry will continue its decline.

Q2. What are the longer term future prospects for the industry in Wales?

As we set out in our summary, we believe that the long-term future for Welsh industry is extremely exciting but only if a new vision is adopted. As things currently stand, we believe the outlook is extremely challenging as Welsh and UK steel will remain unable to compete with global producers whose cost base is considerably lower.

Our vision though is for a steel industry which is based on increasing total UK production by adding extensive scrap steel melting capacity in electric arc furnaces to existing blast furnace smelting capacity. This allows for a much improved management of the raw material pipeline as scrap metal is locally and abundantly available. Crucially pricing will be more stable and lead to a reduction in the swings in costs that have resulted in short term restructuring. As well as controlling costs it also brings with it huge benefits in terms of sustainability and reducing carbon generation. The only major barrier to the use of EAFs is the cost of electricity, which is currently extremely high primarily due to policy and transmission costs. This is why we believe that we must not only review the current carbon tax regime but we must also invest in low carbon and low cost power production to help unlock the opportunities. For this reason we are strategic investors in the Tidal Lagoon projects and why we also are looking at converting our coal fired power station at Uskmouth to biomass. We also intent to develop other forms of sustainable energy at Uskmouth, including the gasification of waste.

We believe that if we transition to EAFs, backed by low-cost and low-carbon power then you unlock the jobs and investment in steel but also the industries which it supports, which has far greater benefits and opportunities.

We understand that there are product acceptability issues associated with EAF steel however we are also convinced that these barriers can be overcome through focussed research and development. A focussed approach to R&D should also be a feature of the Iron and Steel landscape in Wales.

Of course, as the use EAFs increase, the opportunities also exist in the processing and utilising of scrap metal. Currently, we are one of the largest exporter of scrap metal per head in the world and much of this we buy back from countries who add value and create their own jobs by turning it into liquid steel using EAFs. We think the improvements in scrap processing also offer real benefits in terms of employment and sustainability.

We are committed to this vision and are already investing and delivering against it. We hope that we can work with the Welsh Assembly to help unlock the opportunities on a much large scale.



Q3. What is the potential impact(s) of the European referendum result?

As a British Group with a substantial international footprint, Liberty's operations span 5 continents and serve customers in almost every part of the world. We have a clear understanding of our global market, which has been built over the last quarter of a century. While we operate in a multi-currency multi-product environment, our balance sheet has always been based on the US dollar and we expect that its improved performance against the British pound will have a positive impact on the group's financial results. Our global strategy is focused on growth and as a part of it, our overseas business will continue to provide stability and risk diversity while we expand our industrial base.

Regardless of the UK's relationship with Europe, Liberty's plans remain unchanged. The Group remains positive about the prospects of the UK Steel Industry and is committed to working with all stakeholders and interested parties to deliver a better sustainable future for the sector. We believe firmly that effecting change is possible, and that it will have a beneficial impact on both cost and quality. Our GREENSTEEL strategy focuses on producing steel in the UK using local materials and sustainable energy while at the same time continuing to create value and employment in the downstream engineering sector and the wider industry. We have said before and would like to reiterate that Liberty's plans for developing and growing industry in the UK and further afield are unaffected.

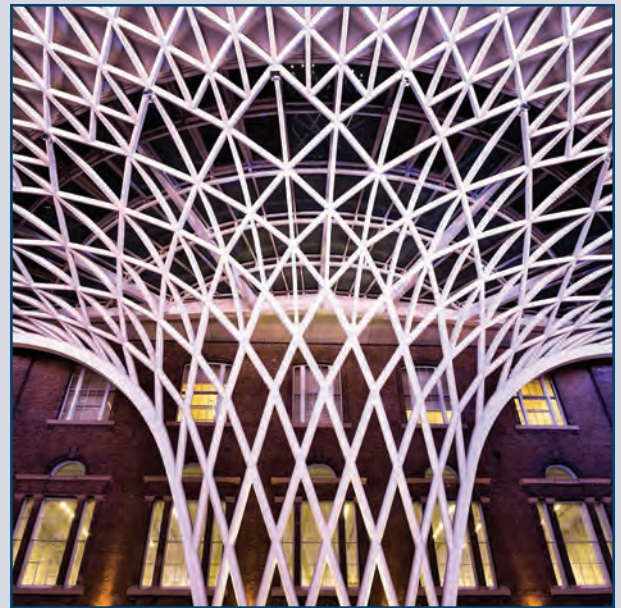
We acknowledge that there will be some challenges in the short term as business and the financial markets adjust and work through the transition period. During this time, our focus will remain on our customers as we continue to provide them with the quality and continuity they require from us. We also expect that the present weakness in the £/€ position will improve the performance of our businesses that target European markets, and that domestic demand for the imported products we provide will remain largely unchanged.

Long term we are optimistic for the future as our plans have never depended on any single type of relationship or destination. We are a group that serves the global economy and as such Liberty will continue to seek and explore any new opportunities across every continent, including all parts of Europe.

FOR FURTHER INFORMATION CONTACT:

Sean Parsons
Head of External Affairs
No 7 Hertford Street, London, W1J 7RH
Tel: +44 7827360891

A bright future for UK steel



A strategy for innovation and leadership through up-cycling and integration

A bright future for UK steel

A strategy for innovation and leadership through up-cycling and integration

Julian M Allwood

Copyright ©2016 University of Cambridge

First published April 2016

ISBN 978-0-903428-38-5

The author has asserted his right under the Copyright, Designs
And Patents Act 1988 to be identified as author of this work

Julian Allwood is Professor of Engineering and the Environment at the University of Cambridge. He worked for 10 years for the aluminium industry, and now leads a research group of more than twenty full time post-doctoral and graduate researchers exploring the opportunity to reduce the greenhouse gas of the energy intensive industries by making less new material. From 2009-2013 he held an EPSRC leadership fellowship to develop work on Material Efficiency, and subsequently won further funding to extend this work, in collaboration with industrial partners spanning the full supply chain of the bulk metals. He is a member of the UK's Energy Research Partnership, was a lead author of the 5th Assessment report of the Intergovernmental Panel on Climate Change, and is an Honorary Fellow of the Institute of Materials, Minerals and Mining.

The motivation for releasing this report in April 2016 at a time of profound crisis in the UK steel industry, is to attempt to bring increased focus on the need to rethink the way we produce and use steel – and to promote the opportunity for the UK to become globally leading in a transformed steel sector, fit for the 21st Century.

The background to this report was published in the 2012 book "Sustainable Materials: with both eyes open" (www.withbotheyesopen.com). The particular focus on up-cycling and integration as a strategy for the European Steel Industry was first presented in an article "The future of steel: time to wake up" in January 2016, in "Materials World".

Julian M Allwood
Professor of Engineering and the Environment
Department of Engineering, University of Cambridge
Trumpington Street, Cambridge CB2 1PZ, United Kingdom.

Contact via Mrs Kirsten Helene Saward
Phone: +44 (0) 1223 748561
Email: khs29@cam.ac.uk

Executive Summary

Tata Steel is pulling out of the UK, for good reasons, and there are few if any willing buyers. It appears therefore that UK taxpayers must either subsidise a purchase or accept closure and job losses. This document presents a third option, to allow a transformation of the UK's steel industry, based on two innovations. Firstly, the global supply of steel for recycling will treble or more in the next thirty years, but the processes of recycling have lacked innovation. At present used steel is generally down-cycled to the lowest value steel application, reinforcing bar. Instead, UK strengths in materials innovation could be applied to up-cycle used steel to today's high-tech compositions. Secondly, the incumbent industry makes undifferentiated intermediate products such as plates, bars and coils of strip with low margins. Much more value is added to steel by downstream businesses that convert these stock products into the tailored components wanted by final customers. New integrated business models could connect liquid steel production to the UK's world-leading skills in architecture and construction, aerospace, automotive and other sectors, to find new value and innovation. This document uses evidence built up over six years of applied research by fifteen researchers funded by the UK's EPSRC and industrial partners spanning the global steel supply chain, to set out the case for this strategy, and propose an action plan.

The global steel industry today has more capacity for making steel from iron ore than it will ever need again. On average products made with steel last 35-40 years and, because it is magnetic, around 90% of all used steel is collected. The supply of steel collected from goods at the end of their life therefore lags the supply of new steel by about 40 years. It is likely that, despite the current downturn, global demand for steel will continue to grow, but all future growth can be met by recycling the existing stock of steel. We will never need more capacity for making steel from iron ore than we have today. The steel industry in Europe, with older assets and higher labour costs than in China, is therefore in a critically difficult position, regardless of local variations in energy and labour costs or the temporary protection of trade subsidies.

The focus of European steel makers in the past three decades has been to consolidate their operations, and to seek innovation in material composition and quality. This has led to impressive technical achievements in the properties of advanced steel which is sold at higher prices. However, this focus has drawn attention away from two areas which are now ripe for innovation:

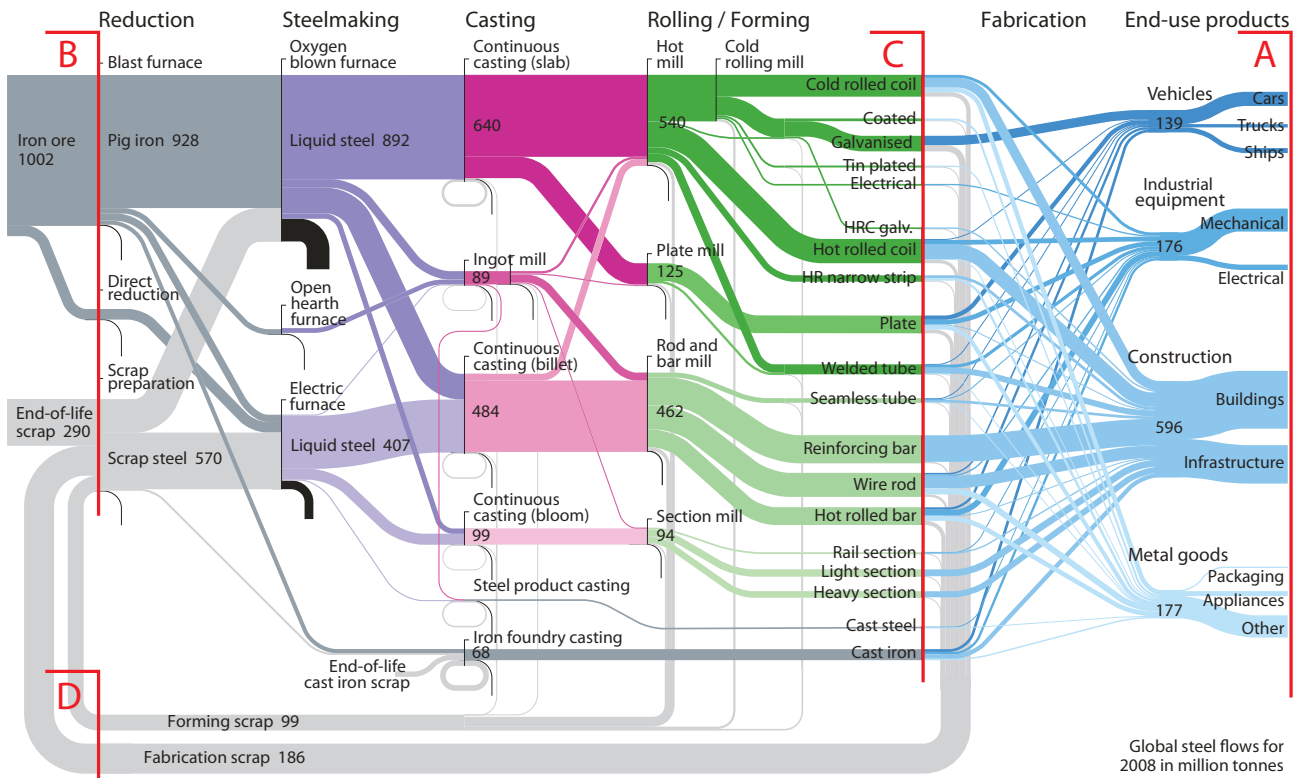
- The quality of recycled steel is generally low, due to poor control of its composition, but there are many technical opportunities for innovation to address this and convert today's down-cycling to future up-cycling.
- The steel industry today makes largely undifferentiated intermediate goods, and fails to capture the value and innovation potential from making final components. As a result, more than a quarter of all steel is cut off during fabrication and never enters a product, and most products use at least a third more steel than actually required. The makers of liquid steel could instead connect directly to final customers.

These two opportunities create the scope for a transformation of the steel industry in the UK. Existing strengths in materials technologies could be re-directed towards upgrading recycled steel. The construction industry that delivered the London Olympics, our leading aerospace industries, and resurgent automotive sector provide the network of partnerships required to re-connect the production of liquid steel to its final users.

In response to Tata Steel's decision, UK taxpayers will have to bear costs. If the existing operations are to be sold, taxpayers must subsidise the purchase without the guarantee of a long term national gain. If the plants are closed, the loss of jobs, income and livelihoods will reverberate throughout the UK steel supply chain. The costs of lost tax income and additional benefit payments alone are estimated at £300m-£800m per year and will ultimately be born by taxpayers. Instead, the strategy presented here enables taxpayers to invest in a long term structural transformation. This would allow UK innovation ahead of any other large player, with the potential of leadership in a global market for used steel that is certain to treble in size.

The government of Denmark's Wind Power Programme initiated in 1976 provided a range of subsidies and support to its nascent wind industry. This leadership allowed it to establish a world-leading position in a growing market. This document proposes that a similar initiative by the UK government could mirror this success and transform the steel industry. Rapid action now to initiate a task force to identify the materials technologies, business model innovations, financing and management of the proposed transformation could convert the vision presented here to a plan for action before the decision for plant closure or subsidised sale is finalised.

Steel in the world today

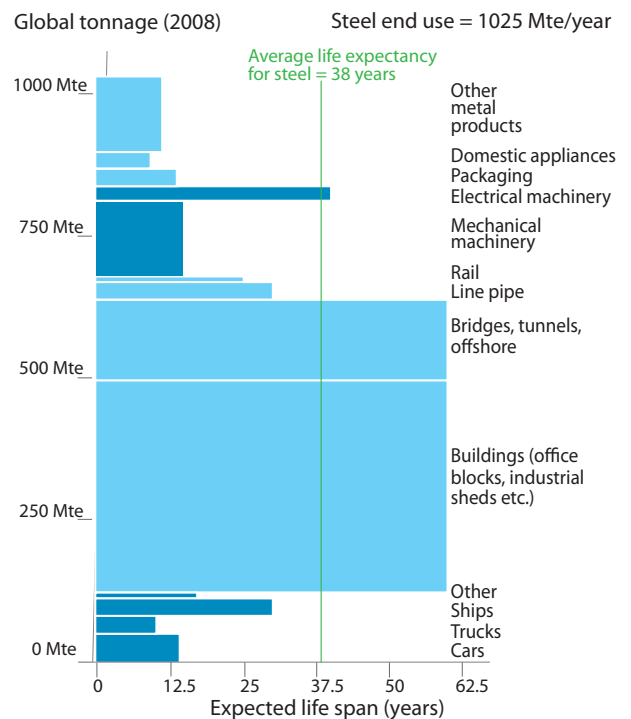


Steel is the world's most used metal, by far, and we make over 200 kg of liquid steel each year for every person alive. The figure above illustrates the 'flow' of steel through the world economy in 2008, with the width of each line proportional to the mass of steel produced. Since 2008, the volume of steel production has increased, but the proportions of the flows have remained similar.

The figure below shows estimates of the predicted lifespan of the new products made from steel in the same year. On average, steel goods last for 35-40 years, but because steel is magnetic it is easily separated from other wastes and is our most recycled material. Apart from ~10% of steel used below the surface (for oil pipes or building foundations, for example) almost all end of life steel will be recycled.

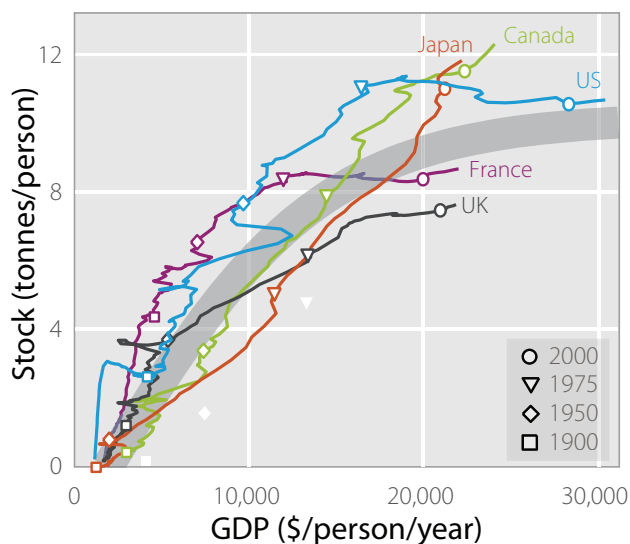
Four key points are marked on the figure:

- A. More than half of all steel is used in construction, with the other major uses being the manufacture of vehicles, industrial equipment and final goods.
- B. Roughly two thirds of today's liquid steel is made from iron ore, with the rest made from scrap, but at present more than half of this scrap is from the manufacturing process itself, rather than from end-of-life goods.
- C. The steel industry makes the intermediate products shown, and sells most of it through stockists to a downstream supply chain.
- D. A quarter of the finished steel made each year (including a half of all sheet steel) never makes it into a product but is cut off in manufacturing because final users want components (such as car doors) that do not closely match the intermediate products (coils of strip steel).



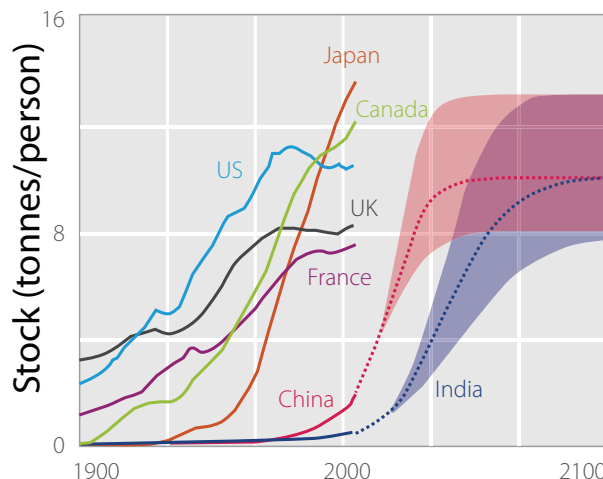
Future demand for steel

Steel is traded globally, so it is difficult to predict future demand from the history of production in any country. However, estimates of the accumulated stock of steel in different countries, show that as countries become richer, their requirement for steel becomes predictable: once we have a stock of around 12 tonnes of steel per person, we need no more.

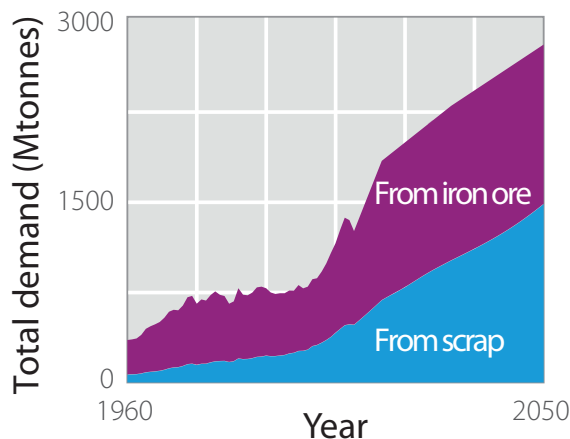


The figure above shows this tendency towards saturation for several developed economies: once we have enough vehicles, infrastructure and buildings we cannot use more, so our requirement for steel is then to replace these 12 tonnes every 35-40 years. This requires about 300 kg of steel per person in the UK per year – 50% greater than the global average.

We can estimate future global demand for steel by looking at how developing economies build up their stocks, and how developed economies maintain them. The next figure shows this pattern over time for the same countries as above, and also gives an illustrative forecast of the build-up of stocks in China and India. The steepest gradient of China’s build up is about now, which is why China’s steel capacity has expanded so much in the past two decades, and why, having passed its peak rate of construction, China now has surplus steel to export.



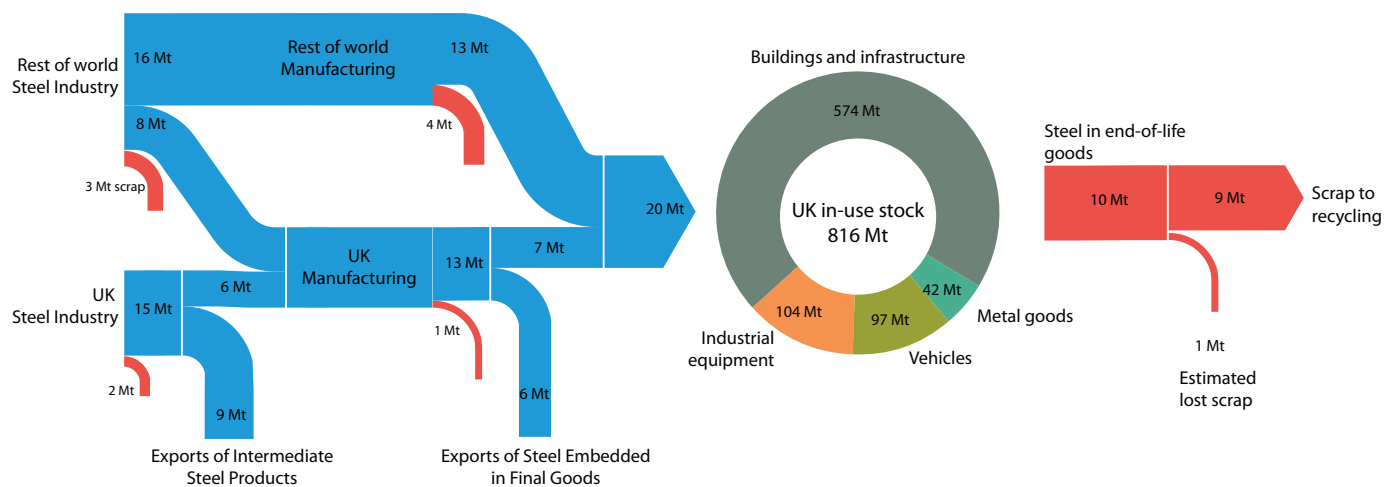
The forecast for future global steel demand shown below is consistent with these patterns of national behaviour.



Despite the current reduction, the figure anticipates future growth in total demand for steel. However, the figure also anticipates the split between steel made from iron ore and steel made from scrap based on the anticipated lifespan of steel products and their recycling rates. This shows that all future growth in demand for steel can be met by recycling: the world will never need more capacity for making steel from iron ore than it has today, but the volume of steel available for recycling will treble in the next 30-40 years.

The current crisis for steel making in the UK is not temporary, and is faced by other European steel makers also. Older assets for making steel from iron ore in countries with higher labour costs have little chance of long term competitive success. Furthermore, if serious action is taken to reduce total global emissions, then without carbon capture and storage – which is still unproven except for enhanced oil recovery – the world’s total production of steel from iron ore must be reduced and more value captured from the existing stock of steel.

Steel in the UK



Steel is not demanded for its own sake. It's embedded in finished products. Demand for finished goods bought or made in the UK in 2007 necessitated the production of 44 million tonnes of steel. 10 million tonnes of this was scrapped during product manufacturing processes. 14 million tonnes were exported in finished goods and 20 million tonnes stayed in the UK, embedded in the stock of buildings, infrastructure, machinery, cars and equipment. Steel used in buildings and infrastructure has a longer lifespan than in cars or equipment. So although the UK stock has nearly stabilised, only 10 million tonnes of steel were discarded. 90% of this was collected for recycling, of which around two thirds was exported.

If the stock of steel stabilises, we can anticipate that over the next two decades, around 20 million tonnes will be discarded annually. In particular, the rapid growth in demand for steel in

construction which occurred in the UK during the 1970's will turn into a boom in demolition and steel recycling.

UK steel industry assets, mainly owned by Tata Steel, were largely constructed in the 1960's and are configured to produce steel from (imported) iron ore. Continuous efforts to optimise and upgrade these assets have achieved remarkable performance, but inevitably, they now lag behind the latest plant installed in China in the past decade.

However, if the UK steel industry were transformed to process used steel rather than iron ore, scrap which is exported at minimum value today, could be upgraded either for higher value export as intermediate goods, or converted into final goods for domestic use or export.

Steel recycling

Until the innovations of the Darby family, Bessemer, Siemens and other 19th Century pioneers, the challenge of steel making was to remove carbon from the liquid iron to avoid unwanted brittleness. Subsequently, materials scientists have explored the addition of increasingly exotic elements from the periodic table to increase steel's strength and tailor its performance for applications such as high strength bridges, lightweight bicycles or high temperature engines. The key innovation in the first phase of this story was to blow oxygen through the liquid iron: carbon in the steel is attracted to the oxygen, leaving behind a purer liquid.

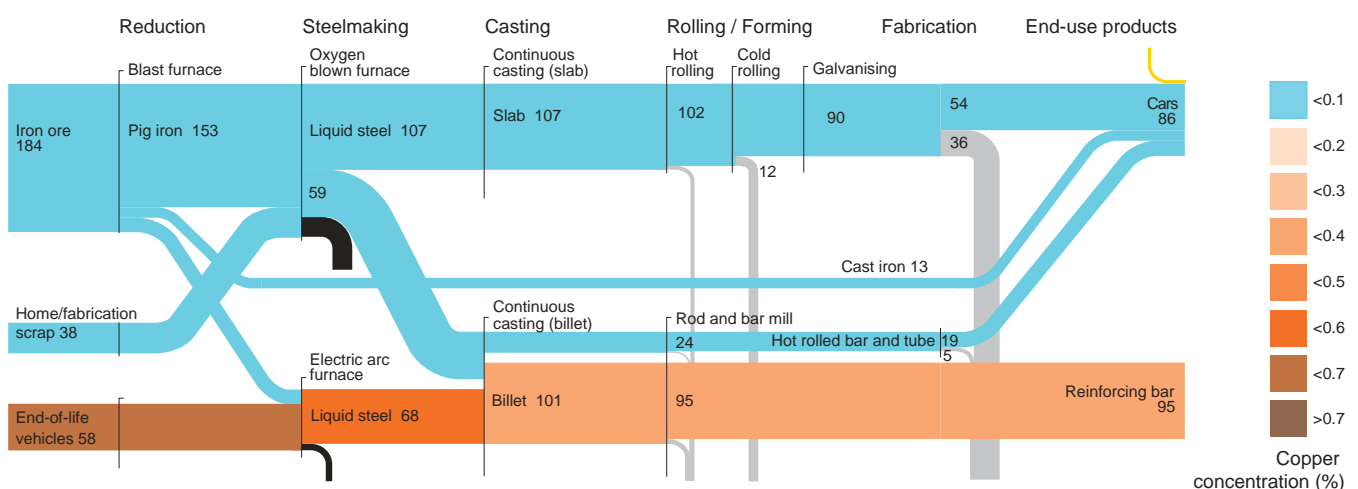
Current steel recycling technology creates a liquid metal by melting a mix of steel scrap in an electric arc furnace, and attempts the same means of purification. However, although oxygen is effective in removing carbon, it does not remove all other impurities, and tin and copper are a particular problem. Tin used to coat steel cans for packaging, and copper used in motors and wiring in cars and appliances, prefer iron to oxygen, so remain in the molten steel, and degrade the performance of the recycled material.

This is illustrated in the figure which is a subset of that on page 2 and illustrates the current use of steel in cars. The highest quality of steel is used to make the latest car models, which include around 750kg of steel and 25kg of copper in electric motors and wiring. Old cars are partially dismantled then crushed and shredded, which mixes the steel with the remaining copper, about 0.7%. The copper cannot be removed from the liquid steel by oxygen blowing, so recycled car steel must be diluted by new metal made from iron ore, and even

then can be used only to make one of the lowest value products – reinforcing bar. Because reinforcing bars are surrounded in service by concrete, they can tolerate up to 0.4% copper, but the flat steel needed to make cars can accept only 0.1%. This un-separated copper would have been worth around £20 per car if collected, and flat automotive steel has a higher value than reinforcing bars.

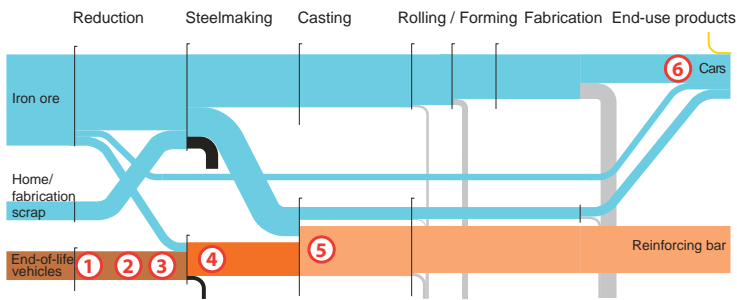
Steel recycling from old cars today is therefore largely down-cycling because of copper contamination. A further consequence of current practice is that many of the valuable alloying elements used in modern steels are lost in the process. Economically and geopolitically important metals such as chromium, nickel and molybdenum used in significant proportions in car steels are not managed at end-of-life, so also end up in reinforcing bars, where their unique properties are not used. Managing the valuable elements embedded in steel stocks could therefore contribute to addressing concerns about the future security of supply of critical metals.

The supply of used steel for recycling is going to treble and current practice is largely down-cycling. This signals an opportunity for innovation, but recycling also has the critical advantage of being much less energy intensive than steel making from iron ore. Steel is made from iron ore using coal, and from scrap using electricity. With today's mix of electricity supply in the UK, the total greenhouse gas emissions from making a steel component from recycled metal are around half those when making the steel from ore. If in future, the supply of low-carbon electricity expands, the emissions associated with recycled steel could drop further, and in the limit, could approach zero.



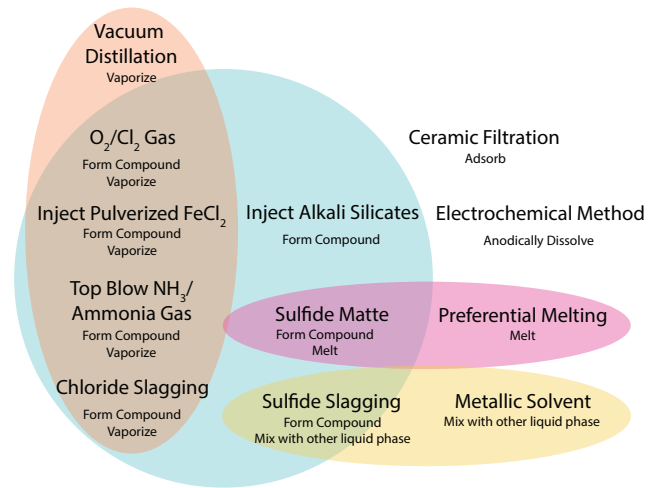
Innovation: up-cycling

In the past fifty years innovation in steel processing has been incremental, and the trophies of innovation in the world of steel have been awarded for new compositions. The strength of steel has risen by a factor of nearly ten, while other properties related to manufacturing, electrical performance, corrosion resistance and many more, have been significantly improved. Not surprisingly, steel recycling has attracted less interest – while recycling is predominantly from internal scrap, there has been less motivation to improve it – and therefore it is a rich field for innovation. Despite the fact that copper and tin are not attracted to oxygen, there are no fundamental physical or chemical barriers to up-cycling by controlling the composition of molten used steel and the figure demonstrates many other areas for new developments:



1. Steel-bearing products at end-of-life could be disassembled with more care, to maintain larger components and avoid alloy mixing. In some construction projects, I-beams could be re-used directly creating the same business opportunity exploited by authorised own-brand used car dealers.
2. Cars and appliances are currently shredded to allow rapid separation of non-metallic components. However this creates mechanical bonds between steel and copper fragments, and other impurities. New approaches to improve this process, for example with robotic cutting and handling, could greatly increase the control and hence value of the separate material streams.
3. Novel sorting technologies, such as laser induced breakdown spectroscopy, are emerging to allow automated sifting of mixed waste streams but have to date had little application in steel recycling.

4. There are many options to purify molten scrap steel other than oxygen blowing. The diagram below presents a survey of many approaches that have been tried briefly in research laboratories in the past 40 years, but abandoned at the time because of a lack of commercial interest. Technologies being developed to handle metals in waste electronics could be transferred to steel.

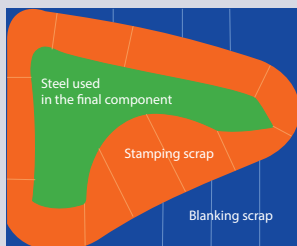


5. New processes, such as belt casting can be developed to allow processing of less pure steels into higher value products.
6. Product designs can be modified to simplify the challenge of steel recycling, by reducing the use of unwanted elements such as copper, or by enabling more rapid separation at end of life.

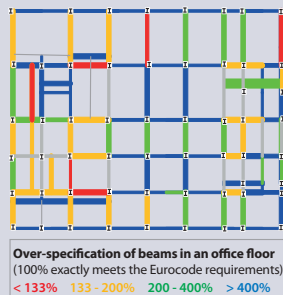
At present, with global over capacity throughout the steel sector, scrap prices are at an all time low, so scrap could be stockpiled. This scrap pile – the UK’s annual steel scrap would cover Hyde Park to a depth of six metres – will become the feedstock of future up-cycling, and can be organised by ease of composition control to allow phasing in of new technologies as they become available.

The UK has always been a leader in materials innovation – the 2010 Nobel Prize in Physics celebrated the first experiments with Graphene in Manchester, the most advanced bainitic steels were developed in Cambridge, and across the UK research and development of electronic, bio, nano and other novel materials is spinning out from research into entrepreneurial business. These strengths could be focused rapidly on the key challenges of up-cycling steel.

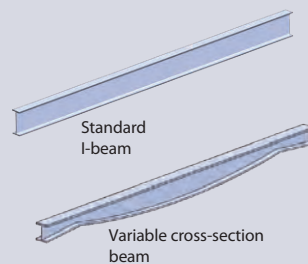
Innovation: integration



Half of all sheet steel is scrapped during manufacturing: in this example, the car panel doesn't tessellate, and extra material is needed for grip while it is shaped



Steel framed commercial buildings must meet the safety standards of the Eurocodes, but on average are currently over-specified by a factor of two



Floors deflect most furthest from the walls, so floor beams should have a variable cross-section. Standard I-beams use 30% more steel than necessary, to no benefit



Buildings are designed for 100 years but on average replaced much sooner, and the steel could be re-used, as in this temporary structure.

Henry Ford famously owned everything from the mine to the showroom, but more recently the steel industry has consolidated to focus on the production of intermediate products: the coils, plates, tubes, bars and sections shown on page 2. These standard forms are globally traded, largely undifferentiated and mainly sold through stockists. As a result, the steel industry operates at a distance from many final users of steel, and the four case studies above illustrate the resulting inefficiencies.

High growth businesses like Apple or Google have intimate connections to their customers to seek every possible opportunity for adding value to their offerings. The steel industry's disconnection from its customers illustrated in these case studies, creates inefficiencies which could be addressed by new integrated business models:

- 50% of all sheet steel is scrapped in manufacturing, the scrap is often returned in mixed form, and may be coated with paint, tin or zinc, creating a challenging recycling problem. Yet the clothing and textiles industry faces a similar problem and returns just 20% of its material as scrap. New cutting and forming processes, and new business models with many customers served from each steel coil, could be developed and implemented by a connected steel industry.
- steel is made so efficiently that it is cheap relative to UK labour, so excess steel is often used to make small reductions in labour costs. A connected innovating steel industry could add more value to less steel by producing

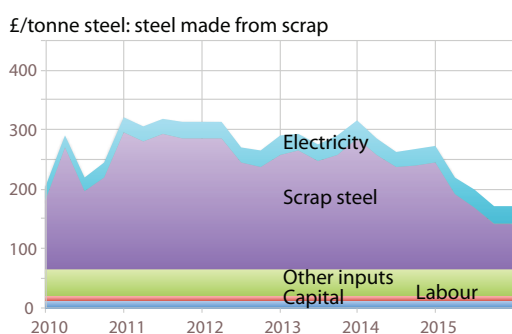
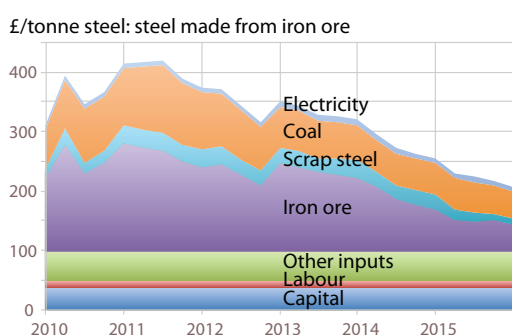
exactly the components required by designers, integrating the liquid metal processes with downstream forming and fabrication, finding new efficiencies in joints and modular designs, and supplying kits of final parts ready for use rather than stock intermediate goods.

- the disconnect between steel makers and users created by steel stockists creates artificial economies of scale aiming at reducing costs to the stockists, not to the final customer. The current disconnected steel industry is in many cases unable to tailor its production to end user needs, because steel makers don't know what's actually required.
- large components, particularly in construction, are often undamaged in service, and could be re-used rather than melted. However the supply-chain for re-use doesn't exist, so re-use imposes very high search costs on interested clients. In contrast, the automobile sector has sought to internalise the value of second hand sales, through authorised re-sellers, providing certification and service guarantees, and holding sufficient stock to match supply with demand. A connected customer-oriented steel industry could do the same.

The UK is globally leading in architecture, construction, aerospace, automotive and other sectors downstream of the steel industry, and has the networks and skills required to seek new forms of business models by finding new and rich connections between steel suppliers and their final users.

Steelmaking costs

The major components of cost in making steel are the purchase of iron ore, scrap and other physical inputs, the purchase of coking coal or electricity, labour and capital costs. The true costs vary by the age, location, design and utilisation of each site and are commercially sensitive, so invisible. However, using a cost model provided by a UK consultant, with data from publically available sources, the figures below give an estimate of the costs of producing one tonne of liquid steel, from iron ore or scrap in the UK over the past five years. In both cases, the cost of producing the intermediate goods that will be sold will be greater than this – due to the casting, rolling or other processes that occur after the liquid steel is prepared, but these costs will be similar for either route.

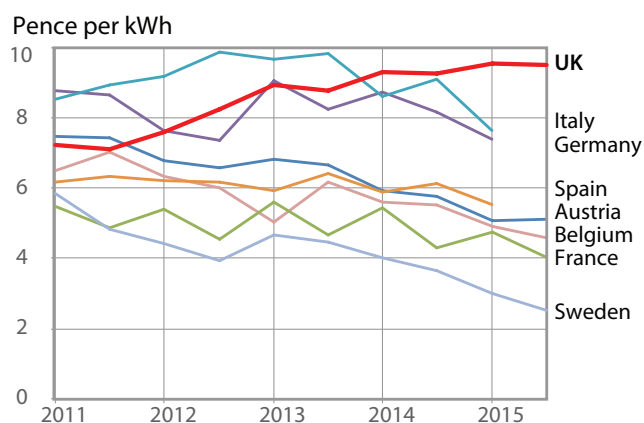


The figures show that

- the largest component of cost in both cases is the acquisition of the raw material – iron ore, coke or scrap. Both have declined significantly during this period, and so has the cost of steel making, driven by global over-capacity.
- energy drives around one third of the cost of making steel from iron ore, and one sixth of the cost from scrap, but both routes are sensitive to variations in electricity prices.
- labour is a relatively small component of cost. Capital costs are more important, and these are the most uncertain elements of these estimates

If the steel made from scrap is down-cycled to lower value applications such as reinforcing bar, these estimates show that the iron ore route remains attractive – the costs of both routes are similar. However, if used steel is up-cycled, it can be competitive against steel made from iron ore. Further, as the global supply of scrap for recycling is certain to expand, the cost of scrap relative to iron ore is likely to fall.

Both process routes are influenced by the price of electricity – even though coal is the dominant energy cost for steel from ore. This is a major challenge in the UK. The figure below, using data from the UK's Department for Energy and Climate Change, compares electricity prices for the largest industrial users in the UK with selected other larger European countries.



UK electricity is significantly more expensive than all other countries shown, and is the most expensive in the EU28. Relative to the median price across the EU28, UK electricity prices are nearly 80% higher.

Electricity prices are strongly influenced by government policy – on capacity planning, generation mix, taxes and other regulation. There are many options to modify these prices, and one example relevant to the proposal in this document, is that the electric arc furnaces used in making steel from scrap are intermittent batch processes. As the UK moves towards a stronger mix of renewable supplies, the challenge of balancing the total demand for electricity from the grid with supply (which is constant for nuclear power stations, but varies with the weather for wind or solar sources) will become more difficult. The electricity requirements for up-cycling steel could be timed to help balance total supply and demand.

Investment

Tata Steel's Port Talbot site, the UK's largest steel plant, has capacity to produce around 4 million tonnes per year of liquid steel from iron ore and roll it into coils of thin strip. Two thirds of the site is used for making liquid steel, with sinter and coking plants to prepare input materials, two blast furnaces and a basic oxygen steel making plant. The remaining third of the Port Talbot site includes continuous casting, hot and cold rolling mills and some other processes for conditioning the strip product, which could be adapted for use with liquid steel made from scrap. In the longer term, there are opportunities for example developed by Nucor in the USA, to create strip steel with very short production routes, directly connecting thin strip casting to rolling mills, to reduce the number of process steps and reheating cycles.

The strategy in this document recommends that, in the light of a certain three-fold growth in global supply of used steel, the current crisis should be a trigger to initiate a future steel industry based on up-cycling. Phasing out the blast furnaces at Port Talbot will create space for three new activities: scrap collection, sorting, separation and storage; electric arc furnaces; downstream processing and intelligence to connect the conventional products of steel making to the final users of steel.

The cost of site clearance is unknown, but there is space available on the site to store significant volumes of used steel. At current low prices, and with most UK scrap being exported, this is an immediate low risk opportunity: the scrap could be sold later if unused.

The capital costs of installing new electric arc furnaces are estimated to be around one quarter of the equivalent costs for

new plant for iron ore, and appear to be of the order of £150-£200 per tonne. These could potentially be reduced as some of the UK's recent capacity in electric arc furnaces has been "moth-balled" so may be acquired more cheaply. Appropriate government procurement strategies may also be able to stimulate early demand.

The costs of creating an innovation park to exploit the integration opportunities identified in this strategy are more about infrastructure than capital: the downstream supply chain that uses steel exists and is strong within the UK. The Catapult centre model of innovation has seen rapid success in the UK, and a new Steel Catapult could be launched rapidly on the Port Talbot site, with incentives provided to draw in the key downstream sectors.

To give an estimate of scale only – true investment costs could only be found with focused and confidential work – assume that the cost of site clearance and re-organisation for scrap management is £100-200m, 4 million tonnes of new electric arc furnace capacity cost around £600-800m, and the establishment of a new Steel Catapult centre required £100-200m. These figures are extremely uncertain, but suggest that the cost of the strategy presented in this document may be of the order of magnitude £1-2bn. If this was provided as a low interest Government loan, the cost to the UK taxpayer of transforming the UK steel industry looks attractive, relative to the cost of redundancies or subsidising a sale. The strategy presented here proposes that this is an investment not a cost: a renewed steel industry in the UK will enable innovation that could not occur in its absence and there is the opportunity for world leadership in up-cycling and integrating steel production with final customers.

The case for government action

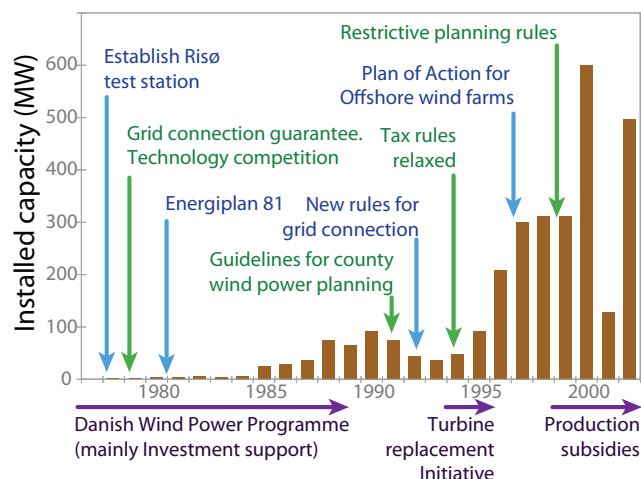
This strategy is not a simple call to install electric arc furnaces at Port Talbot. It is a call for renewal to enable and exploit innovation in areas of UK strength. Installing electric arc furnaces with no other action will allow production of low grade steel products, and the cost comparison between making steel from iron ore or steel scrap shows that this change may continue to need long term government support. In contrast, investing and innovating in steel up-cycling and in integrating steel producers with downstream users, offers much greater opportunity for adding value, while creating the conditions for innovation which can then be exported.

The fact that Tata Steel are selling their UK operations shows that this transformation cannot be achieved by the private sector alone: the investment required to deliver the strategy in this document cannot guarantee the rate of return required by private sector capital markets. Government support is therefore required, and should be justified by recognition of the potential for innovation: the focus of the steel industry on innovating in the composition of new steels made by iron ore has drawn attention away from the potential for innovation in up-cycling; the consolidation of the industry as a supplier of intermediate stock products has prevented the search for innovation in delivering value to the final users of steel components.

UK taxpayers will bear costs whatever happens to the future of Tata Steel in the UK. If the company is closed, 15-40,000 job losses are likely, depending on knock-on effects, and estimating that this leads to a loss of £10,000 of tax revenue per employee and a cost of £10,000 in benefits for each redundancy, the cost of closure will be around £300-800m per year. The cost of subsidising a purchase, with no long term strategy for innovation, is unknown but is likely to depend on some on-going form of subsidy, through reduced tax rates, energy price subsidies or the like. The proposal to provide a low interest loan to allow a transformation of the UK's steel industry at the level estimated on the previous page looks to be comparable or lower than these costs to UK taxpayers, and promises a greater return in the long term.

Innovation in production depends on involvement: for hundreds of years the key steps forwards in product design and manufacture have been made by those who are actively involved, who are most aware of the limits to current practice and the opportunities to do things better. Recent UK strategy has led to the closure of many manufacturing sectors, so the UK can no longer innovate in sectors in which it is not active. The contrast with German leadership in manufacturing is painful, and reflected in the balance of payments of the two countries. While the UK's "High Value Manufacturing Strategy" proclaims the opportunity to create new knowledge-led innovations, the reality is that innovation depends on participation. Few if any UK politicians would fail to describe 3D printing as one if not the only key technology for future production, but in reality it will only ever produce a very small number of components: die-less fusing of powder can make very few useful parts. In contrast, steel provides the backbone to the whole economy. We are purchasing 300 kg of new steel goods for every person in the UK every year, and our buildings, infrastructure, vehicles, equipment and other goods depend on it. There are no substitutes for steel. Being active in seeking value with steel, the UK could lead innovation in this massive product range. Without steel production, the opportunity to innovate in these vast markets is lost.

The Danish Government through its Wind Power Programme from 1976-1989 stimulated the growth of a world leading wind industry that remains dominant today. Over time, Government support changed from provision of test facilities and investment support, through joint company financing, to production subsidies and turbine replacement incentives. Similar evolving pro-action by the UK government today could create a future leadership position in steel up-cycling and customer focused integration.



From vision to action

This document presents a vision based on evidence in the public domain. Action is needed to convert the vision into a basis for decision making – to ratify the main conclusions and to provide confidence in the likely future of a transformed steel industry.

The steel industry itself has lacked leadership. The fact that Tata Steel is selling its UK operations, and that other European steel makers face similar pressures, reflects the failure of incumbent leaders to develop strategies robust to the changing global market for steel. In parallel, the current structure of the UK government has inhibited a focus on steel: many Whitehall departments influence and are influenced by the domestic and international steel market, but none has clear ownership.

Converting this vision into an action plan therefore requires a newly configured task force, able to act rapidly. The components of such a task force might include:

- A steering group with Ministerial leadership, to co-ordinate strategy development to the point that a proposal for investment and support can be prepared for public scrutiny.
- A sub-group on up-cycling. This should include: representatives of the UK's metal scrap industry; the spectrum of UK materials innovation from academia to entrepreneurial success; incumbent users of electric arc furnaces including representatives from Tata Steel in Rotherham, Sheffield Foremasters, Celsa, Liberty House; equipment suppliers including Nucor from the USA, and developers of new technologies for steel sorting and characterisation. The aim of the group would be to

develop a time-line for the achievement of different levels of up-cycling from different forms of steel scrap.

- A sub-group on downstream integration including leaders of successful UK Catapult centres, and representatives from leading UK practices in architecture, construction, design, automotive, equipment and aerospace sectors. The aim of this group would be to scope the potential for innovation through re-examining the entire steel supply chain, and identify a small number of near to market opportunities for demonstration and deployment.
- A sub-group to rethink the business model of the steel industry, including its partnerships, labour and incentive practices, and customer offerings. The priority of this group should be customer-focus, so could draw on leading players such as John Lewis, Google, Apple, Virgin Group, as well as the breadth of UK entrepreneurial success.
- A sub-group on finance and investment including representatives from the Treasury, Investment Banks, entrepreneurs, aiming to develop a credible financial model for the transformation of the sector.

It took nine months to finalise the decision to sell Tata Steel's Scunthorpe Plant to Greybull Capital, in a move which maintains the existing plant but does not address the structural shift that motivates this document. The crisis for the rest of Tata Steel in the UK is urgent, but there is still time to develop an action plan based on this document, in parallel with the exploration of other options, to allow a thorough evaluation of the potential for UK innovation and leadership in a next generation steel industry.

Notes

Page 2: The map of global steel flow was published as Cullen, J.M., Allwood, J.M. and Bambach, M. (2012). Mapping the global flow of steel: from steelmaking to end- use goods, *Environmental Science and Technology* 46(24), 13048-13055. A detailed supplementary information file provides links to all data sources and explains the use of estimation where it was required.

The histogram of steel intensive product life-spans was similarly published as Cooper, D.R., Skelton, A.C.H., Moynihan, M.C. and Allwood, J.M. (2014), Component level strategies for exploiting the lifespan of steel in products, *Resources Conservation and Recycling*, 84 24-32, also with data sources in a supplementary file

Page 3: The estimates of stocks of steel in use were estimated by comparing national statistics on production, trade and waste, by Müller, D. B., Wang, T. and Duval, B., 2011. Patterns of iron use in societal evolution, *Environmental Science and Technology*, 45(1) pp. 182- 188.

The forecast of future steel demand is taken from the International Energy Agency, IEA (2009) *Energy Technology Transitions for Industry*. IEA (International Energy Agency): Paris. p59 fig2.2. We created the forecast of scrap availability based on an estimate of the mix of products in service, using the lifespan data on page 2.

Page 4: The analysis of UK stocks and flows of steel has been accepted for publication as Serrehno, A.,C., Sobral Mourao, Z., Norman, J., Cullen, J.M. and Allwood J.M. (2016) Options

to supply UK steel demand and meet CO2 targets, *Resources Conservation and Recycling*, to appear

Pages 5, 6: This is new analysis that we assembled in order to give the opening plenary lecture at the International Automobile Recycling Congress in Berlin, 16 March 2016, entitled "Purity in car recycling: Supply, demand, the environment, strategy and policy." We are currently writing this up.

Page 7: These case studies are described in our book, "Sustainable Materials: with both eyes open", by J.M. Allwood and J.M. Cullen, published by UIT press in 2012, and available online at www.withbotheyesopen.com

Page 8: The analysis of costs is based on a model made available online by UK steel consultants www.steelonthenet.com. The price data for iron ore, and scrap steel was assembled from a variety of indices, and cross referenced. The data on coal and electricity prices is from online data provided by the Department of Energy and Climate Change.

The comparison of EU electricity prices is from online data provided by the Department of Energy and Climate Change.

Page 10: The figure on Danish wind policy is adapted from one in Buen, J. (2006) Danish and Norwegian wind industry: The relationship between policy instruments, innovation and diffusion, *Energy Policy*, 34, 3887-3897.

WHITE PAPER
THE STEEL INDUSTRY SERIES
PAPER 02 MAY 2016

ELECTRIC STEELMAKING – THE NEW PARADIGM FOR UK STEEL MANUFACTURE



ELECTRIC STEELMAKING – THE NEW PARADIGM FOR UK STEEL MANUFACTURE

EXECUTIVE SUMMARY

The UK market for steel is forecasting strong and sustainable growth across a number of sectors. Despite current turmoil, the UK is well placed to exploit its natural resource of raw materials and intellectual capability, to make a transition to more electric-based steel manufacturing. The key technical barriers to electric steelmaking concern achieving product quality specifications, particularly with regard to copper and nitrogen. New technologies have recently been developed that can partly solve these problems and others are being addressed by innovation projects at the Electric Steelmaking Research Centre, part of the Materials Processing Institute at Teesside. The industry and others have made a specific request to Government to co-invest in the necessary innovation infrastructure and projects, through the Materials Catapult, a proposal from the Materials Processing Institute, TWI and IOM3. In this way the UK can lead Europe by creating the flexible, profitable and innovation-led steelmaking industry of the future.

Market Opportunity

Everything in the world is either made from steel, or with steel. As a material, steel has transformed human life, remains essential for economic growth and helps to raise the living standards of people across the world. No other materials can be made in sufficient quantity, or have the same versatility as steel. In the UK, steel production remains as vital as ever and yet the risk of the wholesale collapse of the UK steel industry has been increasing for many months. The industry is beset by the twin problems of steel from China being sold at below the cost of production and the lack of a level playing field on energy in Europe.

In the rest of UK industry, strong growth is forecast for automotive and construction, a series of large-scale national infrastructure projects in transport and energy have been announced and the aerospace industry is world-leading. These industries and projects require competitive and innovative advanced materials. A domestic steel industry is essential to provide this. Innovation in manufacturing relies on innovation in steel, sometimes with the end user, but often in the supply

chain. Without the foundation of the steel industry, first the supply chain and then the large manufacturers would see a gradual erosion in their competitive position. Put simply, Britain cannot have a high value manufacturing sector without a steel industry, but the industry is not a public service, it must thrive on its own terms to be both profitable and sustainable.

The industry trade body, UK Steel, has made five asks of Government that would level the playing field in Europe, particularly with regard to energy, and to address the dumping of subsidised steel from China in the UK. However, the shake out in the UK steel industry goes far beyond these requests. As a consequence of the current trading conditions, there is a once-in-a-generation opportunity for a complete realignment of the industry, leading to new forms of ownership, new business models and new technologies.

Many of the fundamentals for the UK are already in place; manufacturing industry demands the continual development of new advanced steels, the university sector is world-leading in new steel development and the Materials Processing Institute (MPI), has a 70 year history in delivering cutting-edge process technology for the most efficient manufacture of the materials of today and the future. What is needed is a step change in the fundamental business model, enabled by a switch to different manufacturing technology and by placing innovation at the heart of the business.

Raw Materials Opportunity

Much of the discussion around existing assets, has concerned the relative merits of Blast Furnace steelmaking, as opposed to Electric Arc Furnace (EAF) steelmaking. Quite rightly the initial focus is on securing the existing asset base on a stable footing; however, some consideration must be given to how this asset base can be best developed in the medium to long term.

The dominant steel manufacturing process is the blast furnace route, where iron ore is reduced by coke. This produces liquid iron that is saturated with carbon and is processed in a second stage, the Oxygen Furnace, where the carbon is removed by supersonic injection of oxygen.

ELECTRIC STEELMAKING – THE NEW PARADIGM FOR UK STEEL MANUFACTURE

The liquid steel resulting from this process is then further refined and alloyed to achieve the desired properties for the particular steel product being produced. A proportion of steels are also produced via the EAF route, where usually 100% steel scrap is melted using electricity. Traditionally this route was reserved for smaller scale operations and a more restricted quality range of steels.

Over time, the blast furnace steelmaking route proved to be hugely successful, with British Steel achieving a 500% increase in productivity in the four decades since the current crop of UK steelmaking facilities were commissioned. Continuous, relentless innovation has transformed these production operations, with much world-leading technology being developed here in the UK at the Materials Processing Institute. However, increasingly steel producers have struggled to recover the cost of capital, or to build in the operational flexibility needed to satisfy market demand. At the same time, the scale, quality

and flexibility of EAF steelmaking has been gradually increasing. This, combined with much lower capital costs, has narrowed the differentiator available to the existing production facilities, creating precisely the conditions where an external shock can lead to a step change in the method of manufacture.

Another factor favouring EAF steelmaking is the availability of raw materials. Blast furnaces require iron ore and coal, which was advantageous when the UK had access to indigenous materials. It was the opportunity presented by the availability of these raw materials that drove the geography and development of the steel industry in the UK. As the suitability of these materials declined, the UK industry, as with most of the rest of the developed world, coalesced around large coastal sites with access to deep water ports, for ease of raw material importation.

THE ELECTRIC STEELMAKING RESEARCH CENTRE

The Electric Steelmaking Research Centre at the Materials Processing Institute carries out all aspects of electric steelmaking and metals processing research from fundamental theory to practical implementation on an industrial scale.

The Centre features state-of-the-art pilot steelmaking facilities for rapid steel product prototyping and upscaling of novel steel processes.

The Centre combines the expertise of world-leading scientists, metallurgists and engineers. It has been at the forefront of innovations and process developments in electric arc steelmaking for over 50 years and is renowned globally for this expertise. The Centre works with steel companies worldwide to support the development and implementation of new processes and technologies in electric steelmaking.



ELECTRIC STEELMAKING – THE NEW PARADIGM FOR UK STEEL MANUFACTURE

Forty years on, the UK is once again presented with a unique raw materials opportunity. Having been the first nation to industrialise, the UK has a mature infrastructure and this leads to the generation of an estimated 10M tonnes of scrap steel annually, which is forecast to double in the coming decades. Approximately 6M to 7M tonnes of this valuable raw material are exported every year for processing and then a similar amount is imported back into the UK as steel products.

The UK has a large market for steel that is forecast to grow, access to raw material that is currently exported and the intellectual capital in the workforce, universities and at the Materials Processing Institute that are able to take advantage of this position. Switching the processing technology to EAF, at a relatively low cost, will give a step change reduction in CO₂ emissions, improve operational flexibility and meet future customer requirements for quality and service.

Technology Opportunity

The opportunity to make this technological shift represents the cusp of a paradigm shift in UK steel manufacture that could give the UK the opportunity to emerge as the most advanced and competitive steel producing nation in the world. At the Materials Processing Institute we have recognised the potential for this opportunity and we have marshalled our expertise to launch Europe's first Electric Steelmaking Research Centre (ESRC). It is not all straightforward however; there are steel quality considerations to take into account that have generally been the major limitation on electric arc furnace production. In broad terms these issues are around the presence of both copper and nitrogen in the final product.

Taking copper as the first element of concern, it can lead to cracking in the steel, is present in scrap and is difficult to remove in the metallurgical process. This means that lower copper levels are more difficult to achieve given the larger contribution of scrap in the EAF charge, as compared with the blast furnace / oxygen furnace route. Traditionally this would have been a major limitation on the technical capability of the EAF; however, scrap processing methods introduced as a result of the end of life vehicle directive are now able to achieve sufficiently high

levels of metal separation. Whilst not yet standard industry practice, the opportunity for a forward-thinking steel manufacturer to adopt this technology will both unlock the capability for many difficult to produce steel grades and provide a source of competitive advantages over other producers.

The second area of challenge concerns nitrogen. The electric arc furnaces necessarily result in higher levels of dissolved nitrogen in the steel, due to the difference in the process methodology, as compared with the oxygen steelmaking route and the greater opportunity for nitrogen absorption. Attempts have been made in the past to reduce air ingress into the furnace and these have been partially successful. However, it is technology currently being developed at the Electric Steelmaking Research Centre, part of the Materials Processing Institute, which could create a step change in low nitrogen steelmaking from the EAF. Drawing on a long history of EAF process developments, the Institute is developing a new approach to low nitrogen steelmaking that, once commercialised, could produce steel with nitrogen levels comparable with the oxygen furnace route.

A final area of consideration is the balance between the raw materials charged to the furnace. The opportunity for electric arc furnaces in a mature industrialised economy is centred on the availability of scrap. However, for the production of some steel qualities, it may be advantageous to utilise a mixture of blast furnace hot metal, pig iron, directly reduced iron (DRI), recovered iron units from waste, or hot briquetted iron. In the transitional period between the natural run-down of existing blast furnaces and the run-in of new electric arc furnaces, there would be particular advantages in using such a mix of raw materials. It is also the case that the long term prospects for energy and gas in some parts of the UK, particularly Teesside, give serious opportunity for investment in the production of DRI.

ELECTRIC STEELMAKING – THE NEW PARADIGM FOR UK STEEL MANUFACTURE

Materials Catapult

It is clear that for the UK, or indeed Europe, to take full advantage of this raw materials opportunity, a significant effort will be required in research and innovation. For this reason, the Materials Processing Institute is discussing with the UK Government the creation of a new 'Materials Catapult', to enable the industry to develop and implement the technologies needed to make this leap forward. Catapult is the name given to strategic innovation infrastructure in the UK. The steel industry and the materials sector more widely are currently not supported by the existing Catapult network and this proposal has received widespread support from industry, academia and professional institutions. The Materials Catapult would utilise the existing facilities of TWI, IOM3 and the Materials Processing Institute to accelerate innovation and research commercialisation in the UK materials industries.

The steel industry, essential as it is to our economy, can only recover if the issues of steel dumping and energy prices are addressed by both Government and the EU. However, with this in place, the UK industry can be the global leader in making the step change to a new industry, based on new technology and raw materials opportunities. This will result in the flexible, profitable and advanced steelmaking capability that the UK needs, to enable growth in the advanced manufacturing sector and to continue to support the improvement in our standards of living that has been the unique contribution of steel since its inception.



Chris McDonald
Chief Executive Officer
Materials Processing Institute

Note: A concise version of this paper was published by the Institution of Chemical Engineers (IChemE), in their journal TCE, in May 2016

Chris McDonald is the Chief Executive Officer of the Materials Processing Institute, a not-for-profit industrial research institute, supporting the materials, processing and energy sectors. Chris led the divestment of the Institute from its then parent company, Tata Steel, in 2014.

Chris's background is in industrial research and manufacturing, where he has worked internationally. A graduate of Cambridge University, Chris is a Fellow of the Institute of Chemical Engineers and of the Institute of Materials, Minerals and Mining. He sits on industrial advisory boards at a number of universities, including Oxford and Sheffield and is an associate faculty member at the University of Warwick.

Chris has an interest in innovation management and industry dynamics. He provides expert opinion and support to companies, institutes and government organisations on innovation strategy & management to support growth and inward investment. He is often called to commentate in the media on innovation leadership and the steel industry.

Chris McDonald
Chief Executive Officer
Materials Processing Institute

“ A graduate from Cambridge University, Chris is a fellow of the Institute of Chemical Engineers and of the Institute of Materials, Minerals and Mining ”



Materials Processing Institute

The Materials Processing Institute is an independent, open access and not-for-profit technology and innovation centre working with industry, government and academia worldwide. Support ranges from small scale, site based investigations, through to long term collaborative research programmes.

The Materials Processing Institute has expertise in materials, materials processing and energy, specialising in challenging processes, particularly those involving high specification materials, high temperatures and difficult operating conditions.

The Institute has over 70 years' experience as a leading UK technology provider. Extensive materials processing knowledge is supported by state-of-the-art facilities with a broad range of equipment, from laboratories through to demonstration, scale-up and production plant.

Scientists and engineers work with industry and apply their expertise to develop and implement robust solutions to research and development and improvements for products and processes.

Expertise is spread across a wide range of disciplines, including:

- > Materials Characterisation, Research and Development
- > Simulation and Design
- > Monitoring, Measurement and Control in Hostile Environments
- > Process Development and Upscaling
- > Specialist Melting and Steel / Alloy Production
- > Engineering / Asset Management
- > Materials Handling
- > Minerals and Ores

Research and project management teams deliver support across a wide range of industrial and manufacturing sectors including:

- > Metals and Metals Manufacture
- > Chemicals and Process
- > Nuclear
- > Oil & Gas
- > Energy
- > Aerospace and Defence
- > Mining and Quarrying

MPI Materials Processing Institute

Excellence in Materials & Process Innovation

Materials Processing Institute
Eston Road
Middlesbrough
TS6 6US
United Kingdom

+44 (0)1642 382000
enquiries@mpiuk.com
www.mpiuk.com

