Industrial metamorphosis

A response to the green paper on **Building our Industrial Strategy**

UNIVERSITY OF CAMBRIDGE

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Julian M. Allwood and Alexandra C. H. Skelton

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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 group of twenty researchers exploring the opportunity to reduce the greenhouse emissions of the energy intensive industries by making less new material. He is a member of the UK's Energy Research Partnership, was a lead author of 5th Assessment report of the Intergovernmental Panel on Climate Change, and is an Honorary Fellow of the Institute of Materials, Minerals and Mining. The background to this reponse was published in book *Sustainable Materials: with both eyes open* (www.withbotheyesopen.com).

Dr Alexandra Skelton is an economist, and co-author of the book "Sustainable Materials: with both eyes open". Following a career in policy consultancy, she has collaborated with Professor Allwood for eight years to explore the economic and policy conditions that would lead to reduced material demand.

This document has been informed by a broad base of research completed by the Use Less Group in the past 10 years, and in particular by a Discussion meeting on "Material Demand Reduction" held in Cambridge in September 2016 leading to a special issue of the *Philosophical Transactions* of the Royal Society that will appear in May 2017.

Julian M. Allwood and Alexandra C. H. Skelton
The Use Less Group (www.uselessgroup.org)
Department of Engineering, University of Cambridge
Trumpington Street, Cambridge CB2 1PZ, United Kingdom.

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

Executive Summary

The UK's manufacturing industries have largely declined since 1980, but the globalised industry that serves our expanding demand was developed on the assumption of an energy supply without consequences. In the twenty first Century, either the impacts of harmful climate change or the proactive policies of mitigation will lead to a radical reconfiguration of production. In the eighteenth and nineteenth centuries, Britain led the world with the first industrial revolution, as the first nation to harness fossil fuels for a great expansion of production. This document proposes that in the twenty first century, Britain could lead a second revolution, a metamorphosis from today's shrunken domestic industry to leadership in production fit for a low carbon world. In the short term, this metamorphosis can begin with a focus on supply chains rather than sectors to eliminate hidden wastes, by strategic use of energy pricing and by expanding participation in the design of industrial policy. In preparation for a broader industrial transformation new alliances and engagement could be stimulated aiming to place environmental sustainability and quality of life at the heart of industrial purpose. The document concludes with responses to specific questions raised in the Green Paper.

Through the Climate Change Act, the UK Government has taken the lead in setting emission reduction targets that recognise the science on climate change. This must now be matched by a strategic policy response. This document sets out the basis for an industrial metamorphosis that rises to this challenge, based on three recommendations.

1. Energy prices should remain high

Relatively high energy prices in the UK are a challenge for the energy intensive industries, and are currently relieved by many compensation mechanisms. However, these are applied unevenly and reducing the cost of energy to the largest users dis-incentivises the changes required to create a low carbon future. Instead, energy pricing could be used to stimulate a metamorphosis towards a low carbon industrial base. Brexit creates the opportunity for new forms of border control to allow domestic industry to compete with importers accessing cheaper energy. Furthermore, changed forms of energy price compensation could be designed to support the re-substitution of labour for energy that will be required to allow the conservation of material value.

2. Focus on supply chains not sectors

The energy intensive bulk materials industries supply largely undifferentiated intermediate goods to downstream manufacturing and construction. However, this creates waste: for example, around a quarter of global steel output never reaches a product but is cut off in production, and most products use a third more material than necessary to deliver the same function. Recent government policy has become habituated to this fragmented view. For example, in response to the steel crisis in 2016, the steel committee convened by BEIS and the All Party Parliamentary Group on Steel2020 consulted only the incumbent steel industry with no representation of downstream users of steel. A new focus on supply chains rather than sectors would reveal opportunities for reducing material waste, stimulate the business models that nurture material value over longer lifespans and provide the incentives for re-shoring missing pieces of our industrial infrastructure.

3. Expand participation in policy processes

Industrial production compatible with the emissions reduction targets of the Climate Change Act and without the artifice of "off-shoring" could be rich, creative and satisfying but will be quite different to today's production of short-term commodities sold to disengaged users. Preparation for the required industrial metamorphosis can begin now, through developing experience of different relationships between users and suppliers, through new attention to the design of quality in jobs, and through expanding policy evaluation beyond the use of short-term economic models that dominate today's policy choices. As policy interest in the bulk materials spans many Whitehall departments, this document specifically recommends the creation of a national Materials Forum, modelled on the Energy Research Partnership, to stimulate creative public-private dialogue on materials policy.

The emissions predicament

By setting a binding emission reduction target into law through the 2008 Climate Change Act, the UK government has shown great leadership in recognising the science on Climate Change. However, the definition of the target treats industrial closure in the UK as a success by avoiding responsibility for emissions released in other countries to make goods purchased in the UK. Despite stringent target-setting, there has been insufficient action to deliver change and it is unlikely that we will meet even the narrow production-emissions based targets. International agreements to limit global temperature increases to less than 2°C will require a different approach. A UK Industrial Strategy must have this challenge at its heart in order to put UK businesses at the forefront in a future carbon-constrained world.

Current targets reward UK industrial closure

Both the UK Climate Change Act and the country level commitments under the UNFCCC Paris Accord allocate emissions on a territorial basis. Countries are responsible for emissions that occur within their borders, not for emissions that arise due to the goods and services demanded by their citizens. Fig 1 shows that in 1997 this allocation underestimated the UK's carbon footprint by approximately a third. By 2013 the gap had increased to 50% of territorial emissions. Aside from the effect of the global financial crisis in 2008, UK consumption emissions have grown steadily, rising by 3% in the most recent data year 2012-2013. Setting targets on the basis of production rather than consumption emissions rewards industrial closure in the UK. In contrast, if the UK took responsibility for the emissions associated with its purchasing, its climate targets would align with a strategy promoting a new industrial transformation based on efficient material use, fit for purpose in a low carbon future.

One third of the energy and process related greenhouse gas emissions associated with our purchasing arise from industrial production. The energy intensive bulk material industries that release most of these emissions are already highly efficient and in the foreseeable future it is unlikely that they will be powered by low carbon sources. Mitigating industrial emissions therefore requires making less of the bulk materials. We could live well with much less material production but our industrial system is not currently motivated to achieve this[1].

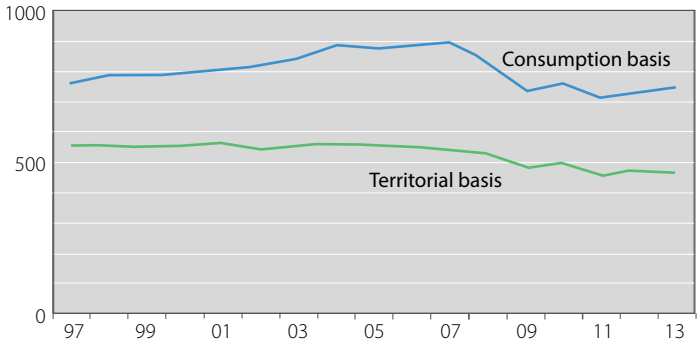

Fig 1: UK GhG emission attributions 1997-2013 (Defra, 2016)

Targets are starting to bite

Within the UK, carbon constraints are becoming truly binding. Suppressed demand following the financial crisis, the phase out of coal in the power sector, changes in the UK industrial structure and the modest but growing contribution of renewables to the National Grid have allowed us to meet the first three UK Carbon Budgets[2]. UK production emissions in 2015 were 38% below 1990 levels exceeding the requirements of the 2nd and 3rd Carbon Budgets. However in their latest report to Government the Committee on Climate Change found current government policies were unlikely to meet the requirements of the 4th and 5th Carbon budgets.

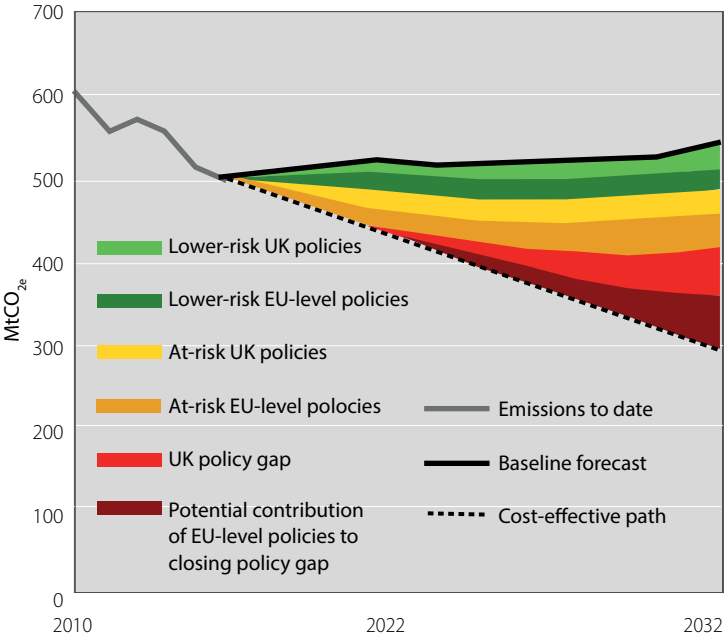

Fig 2: The "policy gap" identified by the CCC in the context of Brexit (CCC, 2016)

The Government has recognised that current plans are insufficient but is yet to publish its Emission Reduction Plan. The "policy gap" identified by the Climate Change Committee creates a real opportunity for the UK government to act to ensure that businesses and consumers face appropriate incentives to deal with the pressing problem of Climate Change now.

No CCS means tackling climate change head on

Climate Change is a problem that arises from cumulative greenhouse emissions: it is the stocks of carbon in the atmosphere that cause changes in temperature, not emissions in any particular year. It is not just the 2050 target that matters but the entire greenhouse gas emissions pathway in the period up to 2050: higher emissions in one period mean that more stringent reductions must be made in later periods. Globally, emissions associated with the continued use of fossil fuels, industrial activity and land use change reduce the permissible stock of emissions that can ever be released by 3-6% a year. At this rate the entire stock of permissible emissions that are consistent with the "less than 2°C" target set by the international community in the Paris Accord will be exhausted in 16-33 years[3]. As difficult decisions on Climate Change are delayed by the international community, the "carbon debt" that has to be repaid in future periods is rising. Today's inaction is imposing on the next generation a high-risk burden of "net-negative" emissions. Indeed 87% of the scenarios that meet a 2°C target in the IPCC's fifth assessment report require net negative emissions in the second half of this century[4].

By permitting reliance on largely unproven technologies the integrated assessment models that generate the IPCC scenarios risk exaggerating the technical and commercial viability of these technologies and fail to emphasise the urgent need for change now. Concerns over the viability of these technologies include: two decades of R&D have struggled to demonstrate the technical and economic viability of fossil fuel CCS; additional problems will arise when attempting to substitute relatively homogenous fossil fuels with heterogenous biomass feedstocks (for Biomass-CCS, the key technology that hopes to deliver net-negative emissions); vast land areas (one or two times the area of India) would be required to grow the required feedstock raising concerns over carbon neutrality, land availability and food production; little thought has been put into the logistics of collating and transporting these vast quantities of bioenergy[5]. Three attempts to fund CCS pilot plants in the UK have failed. By withdrawing funding for these technologies in the 2015 Spending Review, the Government has implicitly put great emphasis on immediate, radical changes on the demand and the supply-side[6]. The Industrial Strategy green paper does not reflect this urgency.

Unilateral action risks carbon leakage

Rising energy costs as a result of climate policies were sited as one of the reasons for the closure of the Redcar steelworks in Teeside in 2015, putting 3,000 people out of work and ending production just before the plant's centenary year[7]. There is no advantage to the environment if climate change policies in the UK cause the relocation of businesses to regions with less stringent environmental policies. However, current policies on climate change are implemented within the wider context of a changing competitive landscape: UK industrial productivity is low (with output per hour worked 25% below that in the USA); the global steel industry is suffering from severe overcapacity (with prices halving 2008-2016); fluctuations in exchange rates cause problems for exporters when the pound appreciates (as was the case in the run up to the sale of Redcar) and benefits exporters when the pound depreciates (as was the case in the immediate aftermath of Brexit when Tata announced a U-turn on the planned sale of the steelworks at Port Talbot).

As shown in Fig. 3 energy costs in the UK are high compared to the rest of Europe. A third of these costs are due to environmental policies, but once compensation schemes are taken into account the effect of these policies is modest. For example environmental policies, and their compensation schemes, increase the cost of steelmaking by approximately 0.1%[8].

If UK businesses are to adapt to a carbon-constrained world they must face appropriate energy price signals that incentivise energy and material efficiency and relay information on where to prioritise efforts. However these signals must not place UK businesses at a competitive disadvantage to their international competitors.

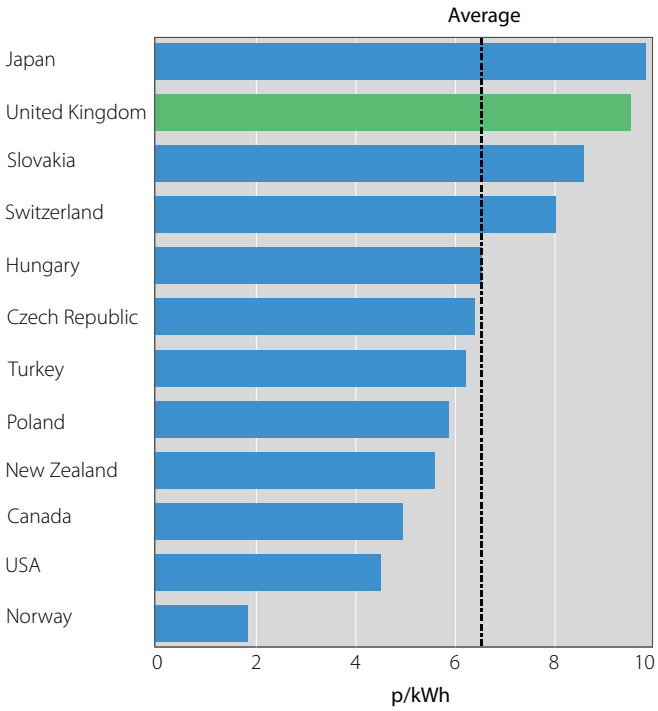

Fig 3: International industrial energy cost comparison

1. Energy prices should remain high

The 2008 Climate Change Act requires that businesses in the UK reduce emissions. Re-locating the emissions intensive industries to achieve reduction targets does nothing to help the climate and disadvantages proactive communities. However a "race to the bottom" risks destabilising the climate, threatening living standards of all future communities. The proposal in the Industrial Strategy green paper to minimise industrial energy costs will hinder efforts to promote greater efficiency in the use of energy and emissions intensive materials that are vital if the emission reduction targets set out in UK law are to be met. Rather than compensating downstream sectors for rising upstream energy costs the Government should seek alternative compensations that are compatible with the environmental constraints that have been set into UK law and that allow fair competition in trade, whilst stimulating innovation towards a materially efficient future.

Energy prices should include environmental costs in order to encourage demand-side responses

Higher energy and material prices offer incentives for the more frugal use of energy and materials. Ideally these prices should increase to reflect the social cost of upstream greenhouse gas emissions that are "embodied" in energy, material and intermediate inputs. This would provide appropriate incentives for substitution towards lower impact inputs and innovation to improve the efficiency with which inputs are used. It would also raise prices of emissions intensive final goods, encouraging consumers to reconsider the bundle of goods they purchase. However, increasing prices of core commodity goods can be both socially and commercially destabilising: higher energy prices have greatest impact on lower income households who pay proportionately more of their income on energy, and even modest increases in energy costs put a strain on companies operating in cost competitive environments. The opportunity for Government is to avoid implementing hasty, reactive compensation schemes when prices start to bite, and instead to explore options to use the full range of fiscal instruments to maintain incentives for effective change, compensating for losses without distorting incentives for demand-side responses.

Carbon prices should set a level playing field and maintain downstream incentives

In the absence of a single global carbon price, industry faces a patchwork of carbon pricing policies. Globally there are now 38 distinct carbon-pricing schemes that cover approximately 12% of global emissions[9]. Businesses within the UK are subject to two carbon pricing schemes: the European Emissions Trading Scheme (EU ETS, a market price currently at about £5/tCO_2) and the UK Carbon Price Support (UK CPS, a floor price that supports the EU-ETS by imposing a minimum carbon price of £18/tCO_2 on electricity generation in the UK. As shown in the box story opposite ('Perverse UK Carbon Pricing for Steel'), these two prices distort incentives by taxing different processes at different carbon prices and by generously compensating for carbon costs, reducing incentives for downstream emissions abatement[10]. What is needed is a carbon price that is levied consistently across sectors internationally through border taxes implemented for example through the Inclusion of Consumption method described in below. In a recent article in the Financial Times Lakshmi Mittal, chairman of ArcelorMittal called for exactly this type of intervention[11].

PROPOSAL: BORDER TAXES

Neuhoff et al. (2016) propose the "Inclusion of consumption" method to reinstate the carbon price in downstream sectors and tax embodied emission intensive materials at the border. Under the proposed scheme, emissions allowances are issued to energy-intensive industries for free under the EU ETS, based on a benchmark plant efficiency. These sectors are not expected to pass on the opportunity cost associated with this free allocation. Instead a charge (dependent on the average carbon intensity of production) is levied on the consumption of carbon intensive materials. This charge is levied on domestic and imported products alike, and takes the form of a liability that is only paid when the good is "released for consumption" i.e. sold to a final consumer or exported. By applying the same levy on domestic and foreign producers, this scheme sets a level playing field and is compliant with WTO standards.

Fiscal instruments should be used to aid the transition

It is common rhetoric that it is not the role of Government to interfere with what people and companies choose to buy. However, in order to raise revenues to provide public services and redistribute income, governments design tax schemes that significantly affect demand-side choices. For example, income taxes raise the cost of labour, disincentivising the substitution of labour for emissions intensive materials in industry. Within the UK, labour taxes increase labour costs by approximately a third. According to Aidt et al (2017) a 1% increase in the

price of labour causes a 0.88% increase in the use of materials in the construction sector and a 1.48% increase in the use of materials in the automotive sector. Crudely extrapolating these substitution elasticities would suggest that labour taxes increase material demand by 29% in the construction sector and 48% in the Automotive sector. This illustrates the fact that fiscal policy across the board has sizeable impacts on the decisions of households and firms and on the environmental consequences of production.

The box story to the side explains how in Sweden fiscal policy is used actively to encourage demand-side behaviours that reduce greenhouse gas emissions. Brexit offers similar opportunities in the UK e.g. reducing the 20% VAT on building repairs that currently disincentivises the retention, restoration and revitalisation of the historic building stock[12].

What can Government do?

The Industrial Strategy green paper proposes a long-term road map to minimise business energy costs while also "*working with stakeholders to explore opportunities to reduce raw materials demand and waste in our energy and resource systems*". These two aims are incompatible. Businesses are used to responding to price signals and these signals offer important information on where to prioritise effort. We suggest that the Government instead focuses on ensuring that price signals operate effectively and that, where necessary, businesses are compensated without unduly distorting incentives. In particular, we recommend that the Government should:

- Listen to calls from business leaders to create a level playing field by implementing carbon taxes at the border e.g. through the Inclusion of Consumption method.
- If the above is not possible, consider alternative forms of compensation for the cost of carbon that are not dependent on energy use. The current compensation mechanisms for indirect carbon costs weaken incentives for demand-side innovation.
- Introduce a more flexible system for varying VAT and other taxes to allow these instruments to be used strategically to aid the transition to a zero-carbon economy.
- Set a requirement for the Committee on Climate Change to include a report on UK consumption emissions alongside UK territorial emissions in its annual report to the UK Government to avoid treating industrial closure in the UK as an environmental success story.

INNOVATIVE FISCAL POLICIES IN SWEDEN

In Sweden there are strategic exemptions from particular taxes that reduce incentives for material efficiency. VAT on repairs to certain goods has been reduced from 25% to 12% and the governing Social Democratic-Green coalition has proposed measures to waive income taxes on repairs to appliances such as fridges, ovens and washing machines. These measures are explicitly aimed at reducing material consumption with a view to reducing embodied greenhouse gas emissions.

PERVERSE UK CARBON PRICING FOR STEEL

The Figure below shows a perverse situation. Differences in the taxes and compensation applied by the UK Carbon Price Support and the EU Emissions Trading Scheme lead to steel recyclers paying a higher effective carbon price than primary steel makers. Yet recycling steel causes only a third of the emissions per tonne of steel.

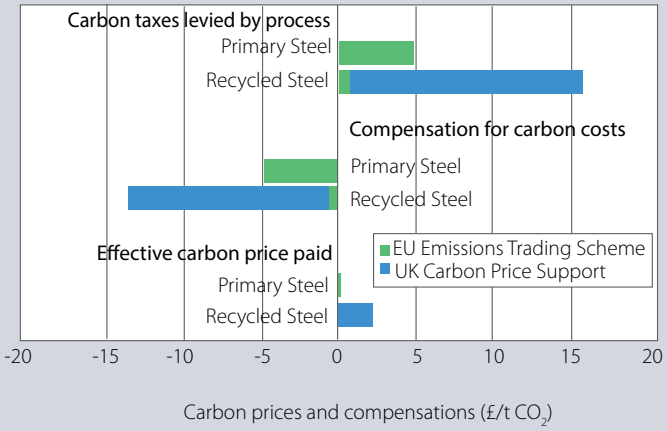

Fig 4: Carbon prices and compensations by steelmaking process (Skelton & Allwood, 2017)

The compensations offered for these costs limit incentives for downstream energy and material efficiency. At least 95 % of EU ETS allowances are allocated to the UK steel sector for free, and BEIS offer compensation for up to 85% of indirect carbon costs borne by energy intensive sectors that are prone to carbon leakage (ie competition with importers with cheaper energy). Given intense price competition, the steel industry claims that it cannot pass on focally applied carbon costs to its customers. If this is the case, then material prices will not increase, and downstream sectors will not face appropriate incentives to innovate.

2. Supply chains not sectors

Focusing Government support on sectors through the proposed "open door" policy risks lock-in to entrenched business practices. Choosing instead to focus on supply chains could release opportunities by channeling efforts to meeting consumer demands – for comfort, mobility, status and enjoyment - in a more efficient manner. The energy intensive bulk materials industries supply largely undifferentiated intermediate goods to downstream manufacturing and construction. This causes both waste and over-design: most products use approximately a third more material than necessary to deliver their function. Firms have strong incentives to optimise within their current operations (or risk losing out to competitors) but there is little incentive to change supply chain practices. Materials could be used much more efficiently but options for change must be identified and evaluated at the supply chain not at the sector level. Government could play a key role in facilitating this dialogue.

There is abundant technical opportunity to improve material efficiency

There are ample technically viable opportunities to improve the efficiency with which materials are used. Fig 5 shows crude steel demand for an office block and a car, distinguishing between steel that is scrapped as yield losses during the production processes, steel that is technically surplus to requirements and steel that is required to deliver the product function. In both examples less than 50% of the steel that is bought is technically required in the final product.

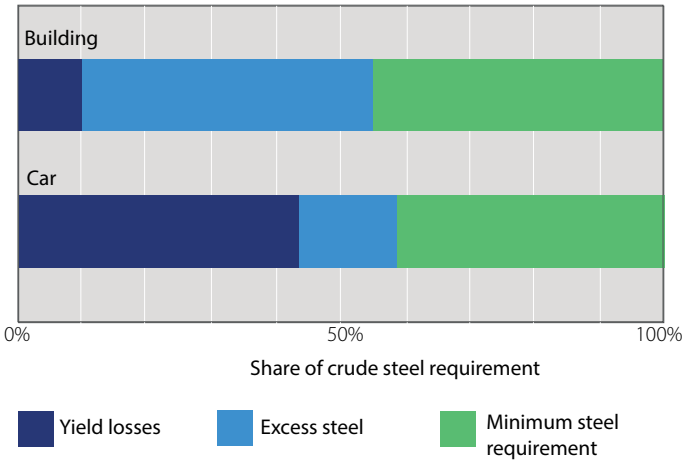

Fig 5: Excess steel in products[13]

A supply-chain approach for steel?

Taking the example of steel, a "sector deal" may see calls for support for existing predominantly primary steelmaking plants in the UK that are suffering due to global overcapacity. An alternative, supply chain deal could see UK scrap merchants – who are due to see a buoyant market as the construction boom of the late 1970s turns into a boom in demolition waste and recycling – working with secondary steelmakers to integrate the currently fragmented upstream scrap markets. As explained in the box stories over-leaf, improved supply-chain coordination with downstream sectors such as the construction sector and the automotive sector could then ensure improved efficiency in the use of materials. Fig 6 shows how key decisions taken by designers have a large bearing on material demand but are made before material cost reduction becomes a priority. Taking an integrated supply chain approach and facilitating a dialogue between design and delivery would help to align incentives and overcome information asymmetries.

What can Government do?

- Convene supply chain discussions to evaluate sector deals by focussing on delivering solutions rather than intermediate goods.
- improve metrics to allow evaluation of material utilisation along supply chains making sure that we extract maximum value from the materials we use.
- Foster "design for manufacture" skills and improve the dialogue across the supply chain between design and delivery.
- Engage in a strategic effort to rejuvenate the UK equipment manufacture sector, a key missing sector that could benefit from supply chain innovation in the UK e.g. through a High Value Added Manufacturing Catapult.

		Automotive		Construction	
		Key decisions	Who is involved?	Key decisions	Who is involved?
Design		Car design, component design, material specification, supplier choice	OEMs, customers	Design concept, dimensions	Clients, architects, planners, Structural Engineers
Delivery		Blank design, nesting, stamping features, production trials	Supply chain	Connection detailing	Supply chain

Decisions that determine material demand

Emphasis on material cost saving

Fig 6: Key decisions that affect material demand[13]

CASE STUDY: Resource efficiency through improved supply chain coordination in Construction

Structural engineers routinely over-specify steel relative to technical requirements: case studies that analyse the efficiency with which steel is used in buildings (its 'utilisation') reveal that 36-46% of steel is surplus to requirements. Fig 7 shows how the distribution of beam utilisation in 27 case study buildings differs across stages of design.

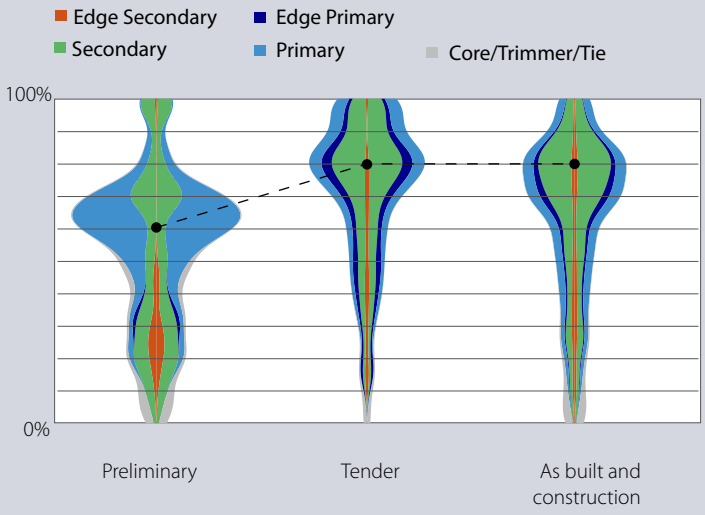

Fig 7: Beam utilisation at different design stages (Dunant et al. forthcoming)

The figure shows that the average utilisation increases from 60% (on average 40% of steel is surplus to requirements) to 80% (20% of steel is surplus to requirements) between the preliminary and the tender stage, but that there is little change between tender and construction. After the tender stage most of the work involves integrating the services and detailing by the structural engineer and connection design by the fabricator. Although connection design can significantly reduce beam requirements there appears to be no feedback loop that allows the beam specification to be revisited once connection design is finalised.

Over-specifying steel relative to technical requirements could reduce costs if reducing the variation in beam specification results in cost savings due to economies of scale in fabrication. However, recent research has revealed that fabricators have little difficulty coping with complex orders and that bulk discounts by beam type are relatively small. Instead, it is likely that over-specification occurs as a defensive design practice by structural engineers who seek to guard against changes in requirements during the design process. Some built in redundancy is inevitable to cope with unforeseen changes to design requirements but this should be evaluated across the supply chain on a project-by-project basis and not be the result of a rule of thumb applied universally by structural engineers.

CASE STUDY: Resource efficiency through improved supply chain coordination in the Automotive sector

Yield losses within the automotive sector range from 30% to 57% with a production volume weighted average of 44%. Yield losses occur across a range of companies and processes. For example the case study car described in Fig 8 was made from 15 different steel alloys and 6 different aluminium alloys with different gauges, coatings and pre-treatment requirements. In all, 100 different sheet metal coils were used to produce 385 components across 21 business units in 13 corporations.

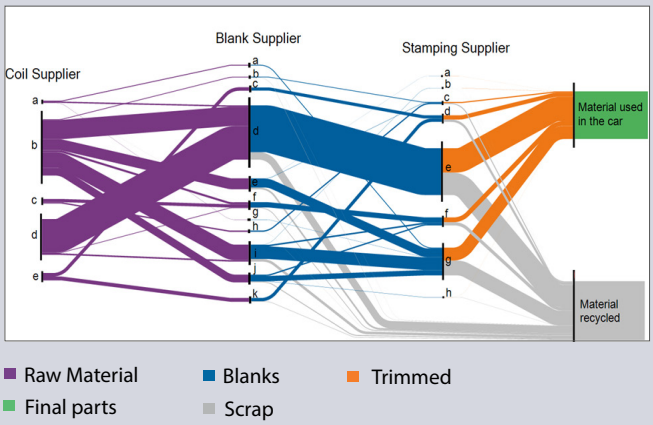

Fig 8: Yield losses in the automotive supply chain (Horton et al. forthcoming)

Horton & Allwood (forthcoming) identify four key stages of car design: design strategy; component design; manufacturing design and component manufacture. Despite initial design decisions having a large bearing on vehicle weight and yield, material utilisation is only formally considered in the latter two design stages. In particular there is a trend towards increasing component capability through designing and manufacturing complex component geometries. This leads to increased yield losses.

Opportunities to improve yield include: changing part shape, changing part nesting and increasing nesting options. Realising these opportunities requires improved feedback between component manufacturers and car designers. Such feedback could explore the opportunity for improving yield through acceptable changes in design e.g. seeking opportunities to rationalise the grade, gauge and coating specification of components within a particular vehicle to increase the opportunity to nest parts.

3. A new form of participation

The UK Government and Civil Service are facing unprecedented pressure in negotiating Brexit and associated trade deals. These negotiations could be an opportunity to further an industrial metamorphosis in the UK, but there is a risk that the systemic opportunities for industrial change that could put UK industry at the forefront of the transition to a carbon constrained world may be overlooked in the urgency of negotiation. The policy development process has little bandwidth to respond in times of crisis and yet it is precisely during these times that there is greatest opportunity for change. We could be better prepared for change by proactive policy design, and by engaging a wider participation in policy development processes, including employees and communities.

Making the most of fleeting moments of change

Evidence on Policy entrepreneurship shows that policy changes during brief windows of public interest, political opportunity and policy readiness. Often, precisely when there is a political appetite for change in response to an immediate problem, there is little time to engage stakeholders and develop policy alternatives. As a result there is a tendency towards consulting incumbent industry players and perpetuating the status quo, rather than taking the opportunity to reconfigure supply chains.

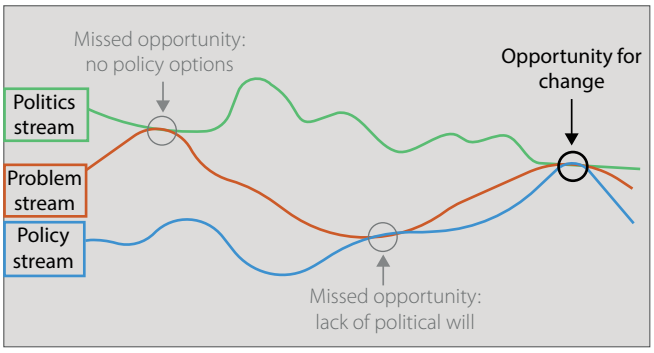

Fig 9: The potential for policy entrepreneurship (based on Cooper et al. forthcoming)

A new form of participation

It is vital to reenergise the policy process to allow a richer set of ideas to be evaluated and ensure policy readiness during fleeting moments of change. The idea of a policy funnel, similar to the design funnels used to scope ideas for product design, shows how options to meet an initial agenda set by government can be developed into a set of actionable policies. This should be an ongoing process that generates a bank of ideas that can be drawn upon at times of crisis, avoiding opportunistic, reactive policy-making that tends to be backward looking and favour incumbent players.

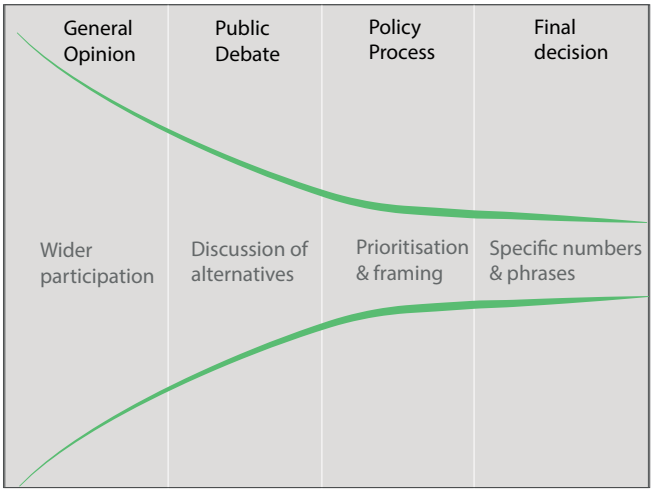

Fig 10: The policy funnel

What can Government do?

- Create a Materials Forum (see below) that comprises a broad range of stakeholders including businesses that represent the full range of supply chain interests, trade union representatives and other stakeholders.

- Aim to influence the negotiations under Brexit and the associated trade-deals to make the most of this opportunity to shape the competitive landscape to acknowledge environmental constraints.

PROPOSAL: MATERIALS FORUM

The Government should establish a cross-Whitehall Materials Forum, comprising a broad range of stakeholders within material-using supply chains to facilitate an inclusive dialogue and evaluate the issues relating to role of materials in society. The Materials Forum could set the strategy for a National Materials Catapult, explore opportunities to reformulate policies following Brexit and establish a set of National Accounts for materials at a relevant level of detail to inform decision-making today and in the future.

A STRATEGIC AGENDA FOR THE MATERIALS FORUM

Whether driven by a climate crisis or by mitigation policy, global industry will in future make less material. The UK could be a leader of the required industrial metamorphosis. However, this change requires a different relationship between consumers and producers and at present there is limited political appetite for strongly directive industrial policy. The actions proposed so far in this document could be implemented today, but in preparation for stronger policy in future, government actions now could: examine the quality of work and of material goods in preparation for developing future metrics of policy; stimulate a wider participation of employee and community groups in corporate and policy decision making; challenge the inappropriate use of narrowly validated economic models for strategic policy making; encourage demonstrators of different experiences of material value.

Quality of work and material goods

The first industrial revolution led to a commoditisation of work, with managers designing tasks to be repeated without variation by disempowered employees. More recently, the ubiquity of computers has created a different homogenisation of the experience of work, disconnected from material reality. Yet the design of jobs is a social choice and one which could be re-examined to the benefit of employer and employee alike. In parallel, the societal benefits of the informal economy and voluntary work merit more attention. Government agencies focused on reducing unemployment could be used to expand our understanding of satisfying formal and informal work.

Recent focus on income metrics creates a monochrome view of quality in material goods. Local planners, for example, have significant potential to influence the heritage and social value of the built environment yet are frequently subordinate to developers whose goals of immediate profit obviate opportunities to create civic monuments and a built legacy to rival that of the first industrial revolution. At a smaller scale, there is a growing body of evidence that goods that invite user participation, for example through personalised styling, repair or adaptation, are kept for longer and have greater value to their owners. Government actions could support changed planning priorities and explore a wider basket of measures of material wealth, including measures of stocks and quality.

Participation in corporate and policy processes

Recent industrial policy processes have typically been reactive, driven by a short term crisis, and are therefore reduced to a rapid dialogue between unprepared civil servants and incumbent corporate interests. A wider dialogue with employees and local communities could allow a broader preparedness and allow greater agility in responding to future crises.

In parallel as large corporations grow ever stronger relative to short term government cycles, the over-riding obligation on company directors to maximise shareholder returns could be re-examined. Other corporate objectives, for example to maximise long term employee welfare, could be considered, along with other designs of boards, such as the German model with employee representation.

Appropriate use of economic models

Alfred Marshall defined four forms of welfare – social, religious, political and economic – yet recent UK policy decisions have been very narrowly focused on short term GDP growth as the over-arching measure of welfare. While the economic models of the sensitivity of GDP to marginal changes around a notional equilibrium have some empirical validation, these models are not appropriate to longer term strategic decision making which involves change far beyond the range of model validation. The government could take action to challenge the hegemony of these narrow economic models, requiring at the least an explicit assessment of how many assumptions are breached when models are used for strategic assessment

Societal Readiness Levels

Many innovation policies are developed using Motorola's famous scale of "Technology Readiness Levels." These describe ten steps from first invention to widespread adoption of a new technology. The metamorphosis anticipated in this document could be described with a parallel scale of "Societal Readiness Levels" on which scale, material demand reduction is at a very early level. In preparation for deployment, a crucial requirement is to develop experience of living well with less material production, and the government could stimulate development of this experience through appropriate use of procurement decisions and innovation policy.

Response to green paper

1. Does this document identity the right areas of focus: extending our strengths; closing the gaps; and making the UK one of the most competitive places to start or grow a business? A low carbon future will be a low energy future so the industrial strategy must be developed to embrace a wider but inevitable transformation. As early movers towards this inevitable goal, the UK could gain market advantage through skills and techniques that could be exported as others catch up.

2. Are the ten pillars suggested the right ones to tackle low productivity and unbalanced growth? If not, which areas are missing? This response suggests the following nuances to the ten pillars: 1. Investing in innovation depends on whether the UK has the complete supply chain of relevant production to exploit the resulting novelty. In order to achieve pillar 1, the UK's supply chains which have been hollowed out by globalisation should be reconnected. 3. A blanket target of upgrading infrastructure could lead to very high material demand, and this should be moderated where possible by adaptation of existing structures. 5. Government procurement has been cited for decades as a potential lever of change towards more environmentally sustainable activity. The right actions are written into procurement protocols but the civil servants charged with implementing the protocols are overwhelmed with other tasks so often unable to deliver. 6. The grounds of trade should be adjusted through border taxes to account for differing environmental standards internationally. 7. Government policies on clean energy, which could be viewed as "picking winners" should be matched by an equal if not greater commitment to energy demand reduction. 8. The sector focus of the green paper should be transformed into a focus on world-leading supply chains. 9. A higher priority than growth is welfare, across a broad range of metrics of quality of life, and government action should prioritise those at the lowest end of any scale of welfare than an average measure.

3. Are the right central government and local institutions in place to deliver an effective industrial strategy? If not, how should they be reformed? This note has proposed the creation of a cross-Whitehall public-private body to act as a "Materials Forum" to facilitate discussions about the bulk materials in the UK which currently have no place.

4. Are there important lessons we can learn from the industrial policies of other countries which are not reflected in these ten pillars? Sweden has the most environmentally sensitive policies and actively uses taxes across the board (including VAT and income tax) to encourage the more efficient use of emissions-intensive materials.

5. What should be the priority areas for science, research and innovation investment? This note draws attention to the need for funding to stimulate new alignments and partnerships to expand the solution space for a low energy industrial strategy, which is unlikely to emerge from continued funding of incumbent players within their existing configurations.

6. Which challenge areas should the Industrial Challenge Strategy Fund focus on to drive maximum economic impact? A low carbon future will be a low energy future and the UK is well placed to become a leader in finding the skills, systems and services that deliver high quality livelihoods with a greatly reduced demand for energy.

10. What more can we do to improve basic skills? Job design receives little attention when corporations are legally obliged to maximise the return to their shareholders as their top priority. An exploration of different options for corporate governance could lead to a quite different focus on employee welfare, and hence job content and skills development.

14. How can we enable and encourage people to retrain and upskill thoughout their working lives? A re-connection of conception and execution within employee jobs could transform motivations from those of wage-slaves to those of self-starters.

27. What are the most important steps the Government should take to limit energy costs over the long term? Energy pricing is a key mechanism to driving down energy demand, so prices should not be reduced. Instead, compensation mechanisms can be designed to redirect the income generated from energy sales and tax to stimulate the activities and innovations that will expand and prove satisfying in a low energy future.

29. How can the Government, business and researchers work together to develop the competitive opportunities from innovation in energy and our existing industrial strengths? A sector focus will perpetuate the retrospective priorities of incumbent businesses, where the supply-chain focus proposed in this document would stimulate the reconfiguration required to find a satisfying low energy future. We can only innovate meaningfully in supply chains in which we are active producers. A critical missing component of the supply chain in the UK at present is in equipment manufacture and a strategic effort to re-develop this sector, for example through a concerted effort via the High Value Manufacturing Catapult, could both create a new channel for connecting UK research strength to industrial operation and be a global leader in developing technologies to support a low energy industrial future.

30. How can the Government support businesses in realising cost savings through greater resource and energy efficiency? High energy prices encourage energy efficiency and material efficiency, and relay information on where to prioritise efforts. Material and energy cost saving strategies could be achieved by new forms of co-operation along the supply chain. The lack of incentives for property owners to upgrade the energy performance of their buildings when the benefits accrue to their tenants are well known. Less well known but of similar magnitude are the opportunities along the construction supply chain to save material and promote building longevity by an earlier and richer connection between client, architect, structural designer, contractor and local planners.

31. How can the Government and industry help sectors come together to identify the opportunities for a 'sector deal' to address – especially where industries are fragmented or not well defined? The Green Building Council and the Government Chief Advisor on Construction proved an effective means to stimulate communication of opportunities across the construction supply chain. These mechanisms could be re-started and enhanced by wider stakeholder participation. Similar combinations of Council and Advisor could be configured for other key supply chains, including those for cars, aerospace, industrial equipment, food and so on.

32. How can the Government ensure that 'sector deals' promote competition and incorporate the interests of new entrants? A focus on supply chains rather than sectors would prioritise the delivery of solutions rather than intermediate goods and this is a better basis for competition and stimulating new entrants.

33. How can the Government and industry collaborate to enable growth in new sectors of the future that emerge around new technologies and new business models? New business opportunities emerge from technical innovations or changes in context. In the certainty that a low carbon future must be a low energy future, the UK has an excellent opportunity during the Brexit process to take strategic action to stimulate innovation in the development of a low energy industrial system with greatly reduced material demand.

Comment questions 29-33: These five questions all address the relationship between government and business, but do not take account of any other stakeholder groups. If the dialogue includes the design of jobs and of high quality living these conversations could also usefully include representatives of trade unions, local communities and environmental lobby groups.

THE TEN PILLARS SET OUT IN THE GREEN PAPER

1. Investing in science, research & innovation
2. Developing skills
3. Upgrading infrastructure
4. Supporting businesses to start and grow
5. Improving procurement
6. Encouraging trade & inward investment
7. Delivering affordable energy and clean growth
8. Cultivating world-leading sectors
9. Driving growth across the whole economy
10. Creating the right institutions to bring together sectors and places

36. Recognising the need for local initiatives and leadership, how should we best work with local areas to create and strengthen key local institutions? Local planning authorities have a powerful opportunity to influence the total material demand of the UK

but currently do not deploy it. This could be stimulated through central government action to inform local governments of their opportunities and of examples of best practice. In the pursuit of more satisfying lives local government support for local arts, community and leisure activities could be given significantly greater priority.

37. What are the most important institutions which we need to upgrade or support to back growth in particular areas? The Whitehall policy development process is at present largely reactive and in assembling rapid responses to immediate public interests tends to draw largely on incumbent players, particularly on larger businesses with existing policy teams. This creates a very narrow level of dialogue over policy development and carries a significant danger that government is disproportionately supporting the owners of large businesses. A different model proposed in this document is to stimulate a much richer policy innovation 'funnel'. A much wider and more representative group of stakeholders could be part of regular dialogue in preparing policy seedlings, which could be refined through a managed stage-gate development process to be ready when public interest and political will meet in future.

In parallel, the document has recommended a cross-Whitehall public-private body to examine national materials issues, designed along the lines of the Energy Research Partnership. No Whitehall department has oversight of materials issues, and a forum for dialogue in this area would both increase communication within the civil service and also allow a wide range of organisations to contribute to policy development.

Notes

1) Allwood et al (2012) explore options for living well with reduced material demand.

2) The UK Carbon Budgets translate the 2050 target from the UK Climate Change Act into 5-yearly committments. The second Carbon Budget demands a 19% reduction below 1990 levels by 2017, the third carbon budget requires a 35% reduction below 1990 levels by 2020, the fourth Carbon Budget demands a 50% reduction below 1990 levels by 2025 and the fifth Carbon Budget requires a 57% reduction below 1990 levels by 2030.

3) Anderson & Peters (2016) interpret the commitment in the Paris Accord to limit Climate Change to "well below 2°C" as a 66% chance to limit global temperature increases to 2°C resulting in a permissible carbon budget of 600-1200Ct CO_2 and estimate that the continued use of fossil fuels, industrial emissions and land-use change reduce this budget by 40GtCO_2 per year.

4) According to Fuss et al. (2014)

5) These concerns are identified by Anderson & Peters (2016)

6) As part of its 2015 spending review, the Government withdrew support for a Carbon Capture & Storage (CCS) Commercialisation Programme that intended to provide capital grants and a Contract for Difference for up to two Carbon Capture and Storage demonstration plants no provision for CCS has been made under Contract for Difference to 2030 and CCS has been removed from the National Infrastructure Delivery Plan 2016-2021.

7) Tighe (2016) describes the situation in Redcar one year after the closure of the plant.

8) Estimates of the cost of steelmaking are based on CCC (2015).

9) Ecofys (2015) conducted a study for the World Bank that identified 38 distinct carbon pricing schemes that cover approximately 12% of global emissions. 85% of the emissions covered by the schemes are priced at less than $10/t$CO_2$.

10) Skelton & Allwood (2017) explore a range of reasons why carbon prices may offer imperfect incentives to reduce greenhouse gas emissions through downstream measures such as greater material efficiency in the use of steel.

11) "The answer, I believe, is the introduction of border carbon adjustments to protect European competitiveness….Europe's politicians need to ask themselves what success really looks like. An outcome where jobs are exported and carbon is imported — with no meaningful impact on total global emissions? Or a fair and equitable policy that incentivises investment and reduces emissions, while enabling the long-term sustainability of Europe's steel industry?" (Mittal, 2017)

12) In a recent response to the House of Lords Select Committee on the Built Environment (HM Government 2016) the Government stated "Under the current legal framework the zero-rate of VAT can only be applied to residential or charitable property that is either newly constructed, converted from commercial to residential use, renovated after a prolonged period without use, or is a listed building that has been substantially reconstructed," the government says in its response. "Until negotiations on our departure from the European Union are complete, our rights and obligations remain unchanged. That includes the application of EU VAT rules." in response to the Lords claim that the 20% rate on repairs to buildings "provides a perverse disincentive to the retention, restoration and revitalisation of historic buildings, and works to prevent owners from looking after them properly".

13) Figure 5 is based on data on the over-specification of steel in buildings from Dunant et al. (forthcoming), assuming 10% yield losses for structural steel. Yied losses for the automotive sector are based on industry data provided by Horton & Allwood (forthcoming). The excess steel in cars is calculated by comparing the industry average car body mass to the car body mass of a Renault Twingo (the lightest 5 seater car in the sample).

14) Summary table based on in depth work in the automotive sector by Horton & Allwood (forthcoming) and the construction sector by Dunant et al. (forthcoming)

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