Energy Efficiency: DEFRA Paper on Scope for Demand Side Measures in Industry

1. Summary

This paper presents Business As Usual and Foresight Scenario baseline projections for industrial energy use and carbon emissions. It also describes the circumstances determining technological advances in industrial processes that may provide further demand-side carbon abatement, and considers the approach to costing the changes required.

2. Introduction

Following on from the previous IAG papers presenting the general approach to demand-side emissions abatement[1], and analysis of the domestic sector[2], this paper gives an initial presentation of the issues relevant to – and very often particular to – industry[3]. As in the previous papers, the carbon projections are derived from an analysis of energy demand and efficiency in relation to sector growth, and the underlying equation is of the form:

$$C = (C/E) * (E/ES) * (ES/GVA) * GVA,$$

where C = carbon emission, E = energy, ES = energy service, and GVA (Gross Value Added) is the industry sector contribution to GDP. The first factor (C/E) is a carbon emissions factor which depends mainly on the supply side, though there is some demand-side choice between electricity and fossil fuels, and between different fuels[4]. (E/ES) rolls up all of the factors to do with the efficiency with which energy E is used to deliver the service ES, whereas (ES/GVA) defines the intensity of the energy service requirement with respect to GDP contribution – generally referred to as structural effects[5].

The main stages are:

1. Baseline energy projection for a "business as usual" extrapolation from historical trends. The main purpose of this is to enable comparison with the DTI modelling work. Energy intensity projections from the DTI model have been available only very recently, so a provisional set of electricity and fossil fuel demand projections had to be used for the analysis, and then compared with the DTI results.

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[1] e.g. contributions to Long-Term Reductions in Greenhouse Gas Emissions: IAG preliminary report to EAP, March 2001.

[2] Energy Efficiency: Domestic Sector: papers for IAG meeting 5 June 2001.

[3] In this context, "industry" comprises Manufacturing and Construction. It does not include the primary energy and energy conversion sectors.

[4] Hydrogen is lumped in with fossil fuels, however it is produced.

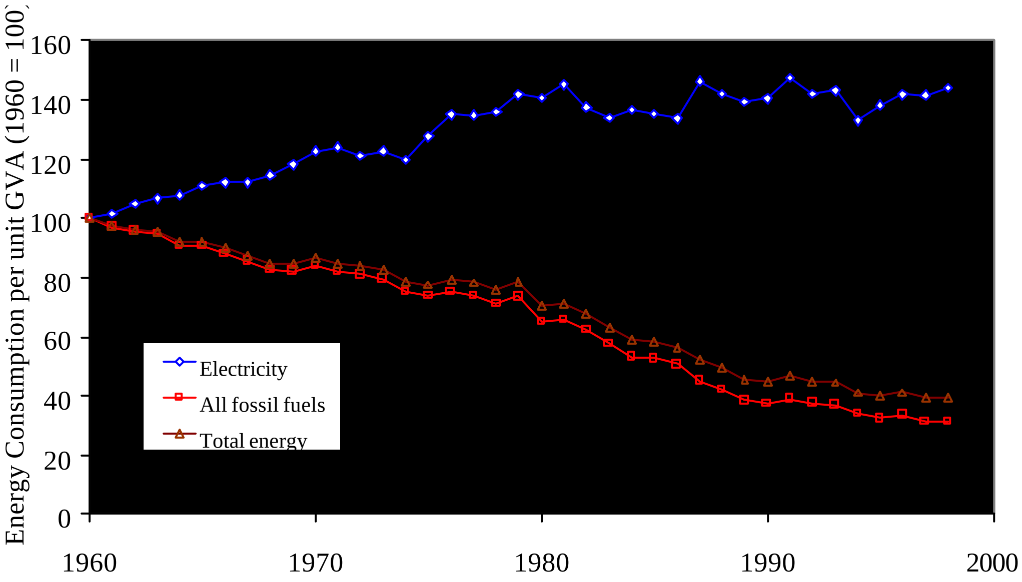
[5] Note that this distinction between efficiency and structural effects only works once one has defined the level at which the analysis is taking place, and inconsistencies easily creep in to hide some of the essential factors. For example, "efficiency" is usually applied to particular processes or pieces of equipment, whereas "structure" is normally though of as a high level effect, relevant to sectors or sub-sectors. Substitution of the process by which the end result is obtained is often the dominant contribution to reduction of energy intensity (E/GVA), and has to be accounted for explicitly in either (E/ES) or (ES/GVA) as appropriate.

2. Baseline projections for each of the four Foresight scenarios. These are interpretations of the scenarios, built on the assumption that the UK follows world trends in each case, but does not take extraordinary measures to reduce its carbon emissions beyond international expectations. They should therefore be broadly comparable with the respective sets of DTI projections, but with the additional feature that energy intensity differences between the scenarios are taken into account.
3. Scope for further emissions reduction via demand-side changes. This is a much broader subject, very dependent on the interpretation of the scenarios, and open to considerable debate, since it is likely to include instances of the UK “going it alone” in some areas. Apart from the “additional energy efficiency potential” of the type that exists at any moment in time – i.e. the scope for catching up with best practice performers – the main options for economically viable demand-side reduction in energy intensity require long term changes in the ES/GVA ratio as well as the E/ES factors, and therefore lie on a distinctly different paths (or paths) within the overall world scenarios. Put another way, process efficiency will still be central to energy intensity improvement, but it will apply to different – most likely novel and unfamiliar – processes. For very large changes, sufficient to meet the RCEP 60% target, it is unlikely that the balance between industry, services and transport will be exactly the same as in the baseline projections for any of the Foresight scenarios for 2050, even if the overall GDP growth is preserved. This paper is confined to an initial identification of the key industrial technologies that can make a significant difference to carbon emissions, in relation to the baseline projection for 2050, and the circumstances in which they could be economically viable.

3. Approach Taken for the Industry Sector

Industry involves a very wide spectrum of energy-using processes, which are constantly changing. Figure 1 shows energy consumption trends over the past 40 years.

Figure 1 Industrial Delivered Energy Intensity Trends



Apart from the enormous improvements in overall energy intensity, the striking feature is the divergence of the trends for electricity and fossil fuels. Three factors can account for most of this change:

1) Major productivity improvements, achieved largely through automation – i.e. more electric motors and electronics;
2) A shift away from traditional heavy industry towards less energy-intensive processes – reducing the demand for direct heating and steam; and
3) Improvements in process energy efficiency, through advanced technology and better management.

There is every reason to expect these trends to continue for the next 50 years, though their weighting will change – e.g. there are limits to how far heavy industry can continue to shrink, and thermodynamic limits to the efficiency of some basic processes.

Although there are a few energy services which span most or all of the industry – e.g. motive power, heating, lighting, compressed air, etc, many of the most energy intensive processes are sector-specific. Hence a forward look for industrial energy use needs to take account of individual sub-sectors. For convenience the set of 16 sub-sectors used in the ETSU/DETR Global Atmosphere Division projections (GAD Report)[6] is used, plus Construction (which although not an intensive user of energy, is important in that it represents about 20% of industrial GDP contribution). Together they correspond very closely with the industry definition used in DUKES.

The RCEP report classifies energy demand using three categories: (1) High Grade Heat; (2) Low Grade Heat; and (3) Electricity. This is well suited to describing industrial energy use, and is followed here. Comments on the likely trends within individual subsectors are given in Annex 1. Although there are some areas of flexibility, scope for switching between electricity and fossil fuels is quite limited in industry[7], so all of the analysis follows each energy source separately.

For the purposes of understanding what a baseline projection for 2050 might include, as regards the processes responsible for energy-related carbon emissions, one needs electricity and fossil fuel projections for each of the 17 sub-sectors. To do this on a technology basis would be a mammoth task, and of little significance since many of the processes (and products) will have changed out of all recognition by 2050. Instead, a top-down approach has been taken, starting with extrapolations of the historical trends for electricity and fossil fuel demand. As explained above, the DTI energy intensity projections were not available at the time this work was done, but subsequent comparison (see Section 4 below) shows broad compatibility. The 2050 electricity and fossil fuel projections were then allocated amongst the 17 sub-sectors in an iterative process. This also included:

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[6] Industrial Sector Carbon Dioxide Emissions: Database and Model for the UK. ETSU Report series for DETR, 1993-2000.

[7] The main industrial use of electricity is in motors. Other inflexible areas are electronic equipment and lighting. Electricity can be used for heating of all kinds, but under current energy price differentials it is more cost-effective to use fossil fuels for non-specialised applications. Other significant switching would entail process substitution, e.g. between electric arc and blast furnaces (or low carbon fossil fuel technologies) for liquid steel production.

(a) apportioning the DTI-specified baseline industrial GVA growth amongst the sub-sectors, and

(b) considering the energy intensity (electrical and fossil fuel intensity) trends simultaneously, together with

(c) likely structural changes (e.g. relative contraction of the basic metals industries and increasing growth of pharmaceuticals in relation to basic chemicals).

Because there is generally a steady increase in GVA per physical unit of output in most industries, due to productivity and quality improvements, it is quite difficult to think about long term growth of industrial output purely in GVA terms. Hence steps (a) and (b) were actually performed using estimates of physical output growth (e.g. tonnes of liquid steel etc.), relating this to overall GVA growth via the current GVA for each sub-sector)[8]. By this means, a self-consistent and complete picture of BAU energy consumption was produced, albeit subject to a large number of debatable judgements about relative trends, innovative changes, etc.

Baseline projections for the Foresight Scenarios were then developed relative to BAU, using a similar approach, apportioning the higher or lower growth to each of the sub-sectors[9], and including the projected changes in energy intensity or process balance (affecting electricity/fossil fuel ratio) judged to be likely for each of the individual scenarios.

4. Business As Usual Energy Projections

The BAU projections for industrial electricity and fossil fuels are summarised in Table 1. The projected fraction of UK total demand is an approximate estimate derived from applying a similar projection methodology to the whole economy, and shows the considerable reduction in significance of industrial fossil fuel demand, whereas the electricity share is projected to increase.

	Demand (Mtoe)					Percentage Change	Fraction of UK energy demand	
	1990	2000	2010	2020	2050	1990-2050	1990	2050
Electricity	8.7	10.0	10.6	11.3	13.6	57%	6%	8%
Fossil Fuel	30.0	25.6	21.6	18.7	15.9	-47%	20%	9%
Total	38.7	35.6	32.1	30.0	29.4	-24%	26%	17%

Table 1 Business As Usual Baseline Energy Projections for Industry

The sub-sector shares of GVA, electricity and fossil fuel demand are illustrated in Figures 2, 3 and 4 below, which show the 2050 shares relative to 1990. Given the

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[8] This includes an implicit assumption that GVA growth per physical unit of output is comparable for all sectors. Although an approximation at best, this is probably no more of a limitation that several other factors.

[9] Domestic demand is dominant for some industries, e.g. construction and building materials, so demand is dependent on population and household trends. The SPRU population projections used in the DTI modelling are inconsistent with the BAU projection based on the ONS forecast, so an alternative set of Foresight trends is used here. Populations in 2050 are assumed to be as follows (in millions): BAU = 65; WM = 66; PE = 64; GS = 63; LS = 62.

time span to be bridged, these can only be plausible estimates at best, but a few points are probably significant even that far ahead:

- The Basic Metals and Chemicals sub-sectors are by far the largest consumers of energy at present, and their futures have the greatest significance for 2050 consumption. Both now operate in truly international markets, and world markets can have major effects on the extent to which UK demand is met internally. In this projection, it has been assumed that UK steelmaking capacity is reduced by 50%, and that primary aluminium smelting moves abroad to take advantage of low-carbon electricity sources, e.g. hydro. Chemicals retains its share of UK and world markets. Essentially non-traded sectors such as Construction, Cement and Bricks remain relatively static.
- Electrical engineering is shown as the fastest-growing industry, though it is not amongst the most energy-intensive, and much of the market is supplied from abroad. Its products are of course used to an increasing extent in all industries, explaining the rise in electricity demand.

Figure 2 Sub-Sector Share of Industrial GVA

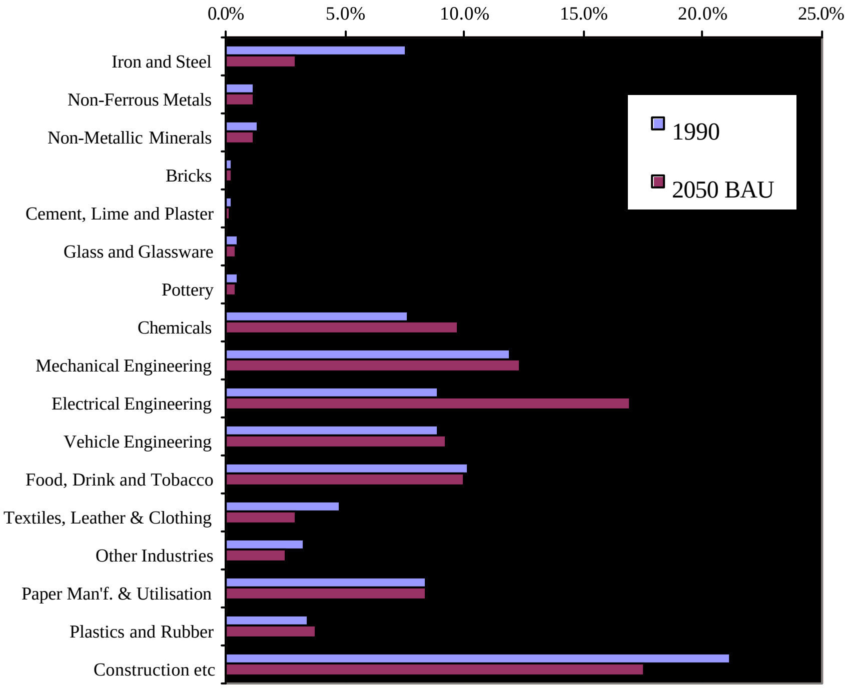


Figure 3 Sub-Sector Share of Industrial Electricity

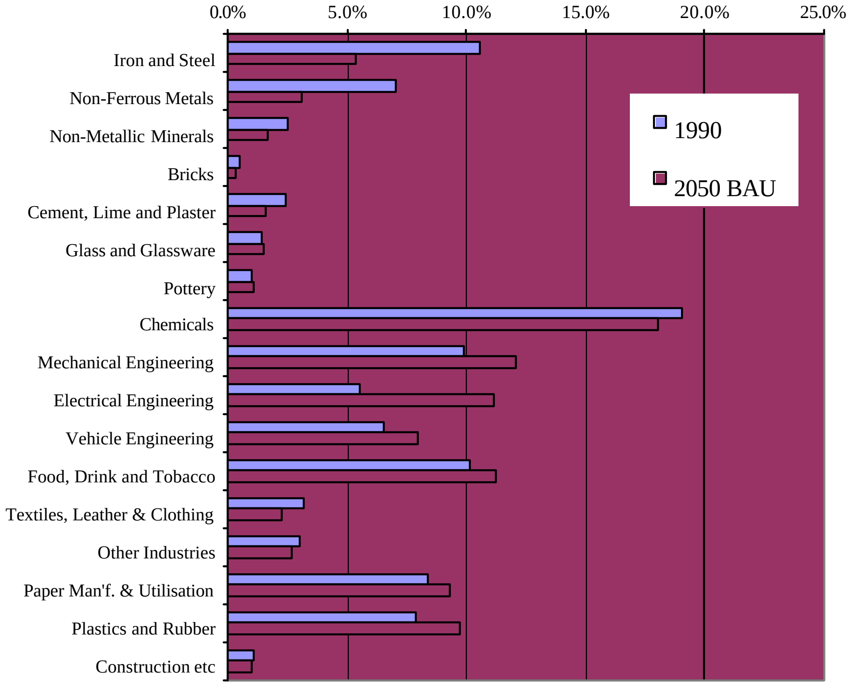
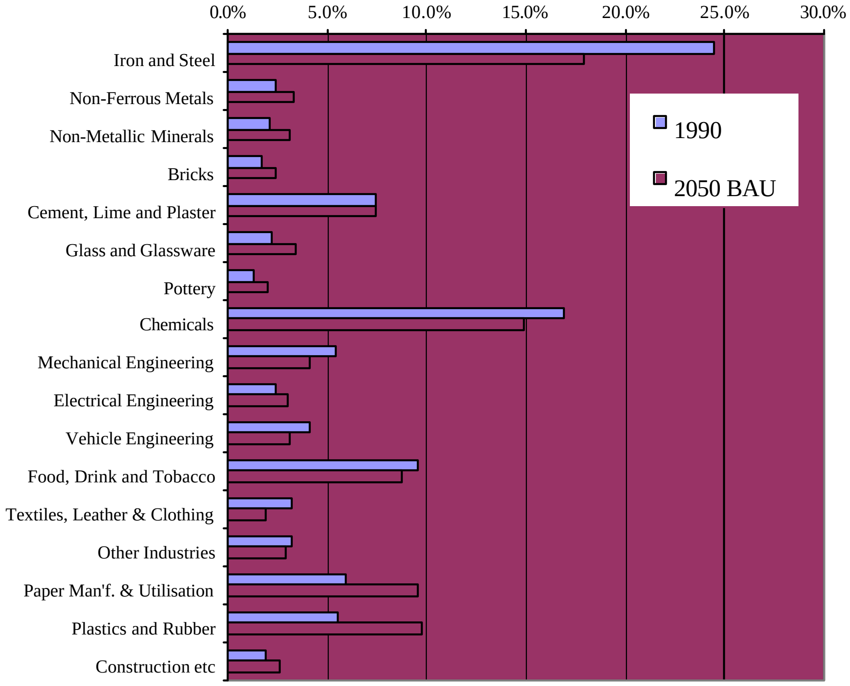


Figure 4 Sub-Sector Share of Industrial Fossil Fuels



As in the RCEP scenarios for 2050, it is assumed that fossil fuel demand for high and low grade heat will be supplied by natural gas where technically possible. This applies to almost all major processes except for reduction of iron ore, where coke-fuelled blast furnaces are assumed to be still in use (at 50% of current capacity). Sub-sector shares of high and low grade heat demand are detailed in Annex 1. Electricity is assumed to be supplied by a combination of central and distributed generation, but as in the DUKES convention for CHP, all locally generated electricity is treated as being part of the supply side, rather than a derivative of fossil fuel demand. Further comments on technological development are given in Sections 5 and 6 below, in the discussion of the Foresight baselines.

In relation to the recent DTI energy intensity projections, this BAU picture lies between Variant A and Variant B, though much closer to the former (i.e. to the extrapolation from historical trends, rather than from trends including the 2000-2020 projections). Overall, the BAU projection above represents an average annual energy intensity improvement of 2.4%, as compared with 2.8% for Variant A, and 1.23-1.33% for Variant B. It has not been possible to compare electricity and fossil fuels separately.

5. Foresight Scenario Baseline Energy Projections

Baseline energy projections for each of the four Foresight scenarios have been obtained as described above, using the BAU baseline of Table 1 as the reference, and following the DTI assumptions on GDP growth. The quantitative differences are illustrated in Table 2, and Figures 5-7 below. These show sub-sectoral shares, rather than projected absolute differences, to illustrate the importance of opposing factors.

	2050 Energy Demand (Mtoe)				
	BAU	WM	PE	GS	LS
Electricity	13.6	13.8	13.8	12.5	10.9
Fossil Fuel	15.9	15.2	16.6	12.5	14.8
Total	29.4	29.0	30.5	25.0	25.7

Table 2 Foresight Scenario Baseline Energy Projections

Differences in relative growth under each scenario (see Figure 5) are intended to allow for differences in:

- the extent to which markets are serviced by UK manufacturing;
- pattern of demand, e.g. plastics rather than metals; recycling; etc;
- demographics.

Relative to BAU, the projection model includes sub-sectoral differences in physical output, mainly within the range of +10% to –20%. As in the BAU, there is enormous uncertainty in most areas, and the detail in the model is there only for completeness and self-consistency. Commenting just on those areas where there is a reasonable expectation of general effects persisting for the next 50 years:

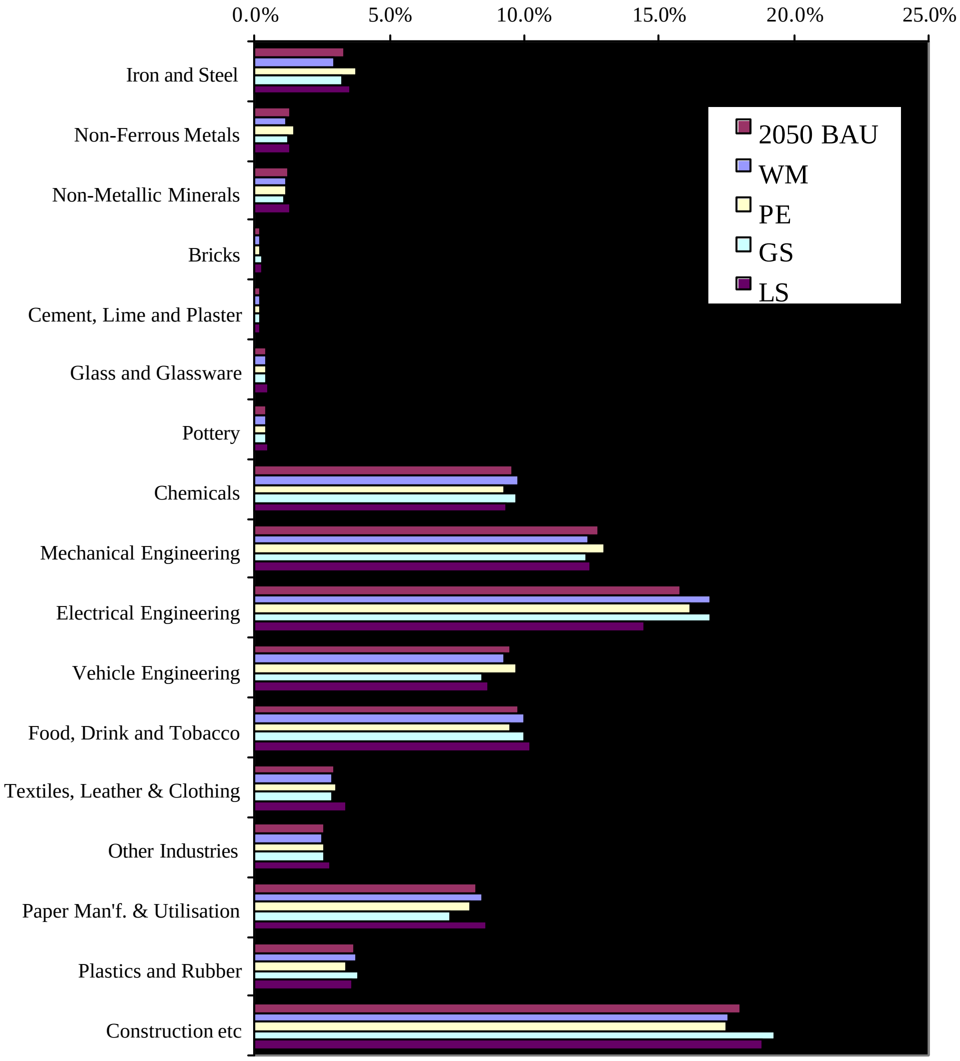
1) Construction and building materials are provided locally, and driven by demographics as well as overall growth. These effects may add together or cancel. Hence although the population scenario for LS is the lowest, the very low GDP growth for the whole of industry dominates, and the share of total GVA for Construction, Cement, Bricks and other mineral products is larger than in the higher growth WM and PE scenarios. Under GS, the fraction is even higher due to an increased rate of buildings stock replacement and refurbishment.

2) ‘High-tech’ industries are likely to benefit most under the higher growth scenarios, and GS in particular is likely to bring about an increase in engineering

output concerned with renewable generation, improved transport systems and other low carbon technologies. LS is not seen as providing the resources for major manufacturing expansion, even if the desire is there.

3) A balancing factor for high-tech industries in the WM and GS scenarios is the extent to which demand will be met by imports. Hence the share of GVA may actually be higher under PE for some industries, even though UK market demand is higher under WM and GS.
4) Heavily traded goods, such as textiles, food and paper, appear with a higher share under PE and LS.
5) Security of supply within the UK is likely to be an issue for basic metals under PE and LS, so a higher fraction of manufacturing remains in the UK.
6) Vehicle manufacture is given a lower share under GS, on the assumption that transport demand per capita will be lower than under BAU or WM.
7) Paper manufacture is reduced under GS, on the assumption that IT will be developed to an extent that demand is actually reduced.
8) Recycling is assumed to increase under all scenarios, to differing degrees, but this is expected to have more of an impact on materials and energy resource productivity than on GVA, or GVA share.

Figure 5 Sub-Sector Share of Industrial GVA



One conclusion that emerges from Figure 5 is that the differences in GVA share are relatively modest, even though individual sub-sectoral factors in the model differ by 35%. It simply illustrates the point that many of the factors tend to balance out to a large extent. This is likely to be true even if the individual differences are argued to be more radical than has been assumed here.

Differences in the shares of electricity and fossil fuels (Figures 6 and 7 below) also take into account:

- rates of development in industrial technologies;
- fuel switching as a result of process substitution;
- recycling; and
- attitudes to energy efficiency and energy management.

Relative to BAU, the combined effects of these factors have been given values mainly in the range –20% to +20%, and the most significant points are believed to be:

a) Technological advancement tends to improve energy intensity under any scenario, and also tends to increase the electricity:fossil fuel ratio. These factors are therefore GDP/GVA growth-dependent.

b) The direction of technological advancement is influenced by attitudes to carbon abatement (directly, or indirectly via energy prices or carbon tax, etc), via normal investment choices. Usually there will be cost-effective options which go at least marginally beyond current average energy/carbon emissions performance, so GS can achieve better energy intensities than BAU under similar GDP growth. As with general technological advancement, there is likely to be more reduction of demand for fossil fuels than for electricity. GS alone includes a switch from blast furnaces to methane reduction of iron ore (similar energy requirement, but lower carbon), and substantial replacement of distillation by membrane separation processes in the Chemicals sub-sector (substantially reduced fossil fuel demand).

c) Economies of scale are important for major technological energy intensity improvements, and LS is unlikely to be able to deliver the changes that are possible under GS. Increased fragmentation of manufacturing facilities is also likely, to a lesser extent, under PE. The lower demand under LS increases the fraction that can be met by recycling (altering the balance between electricity and fossil fuel usage in the Iron & Steel sub-sector, for example), but also reduces the scope for process integration in the Chemicals industry (and others), thereby increasing energy intensity relative to BAU.

Overall, the energy projections in Table 2 show the balancing of these effects, to the extent that there is little difference between BAU, WM (higher growth, more advanced, efficient technology) and PE (lower growth, poorer energy performance). The remaining pair of scenarios, GS and LS, also have similar total energy demands, for the same kinds of reason, but the balance between electricity and fossil fuel demands has diverged significantly because of their different technological development paths. Of the BAU fossil fuel demand, approximately one third is associated with high grade heat, and two thirds with low grade heat. Similar fractions apply in the other scenarios[10], and further details are given in Annex 1.

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[10] In GS, which includes more radical technological changes, the reduction in high grade heat carbon emissions in ironmaking is balanced by the reduction in separation process low grade heat demand in the chemicals industries.

Figure 6 Sub-Sector Share of Industrial Electricity

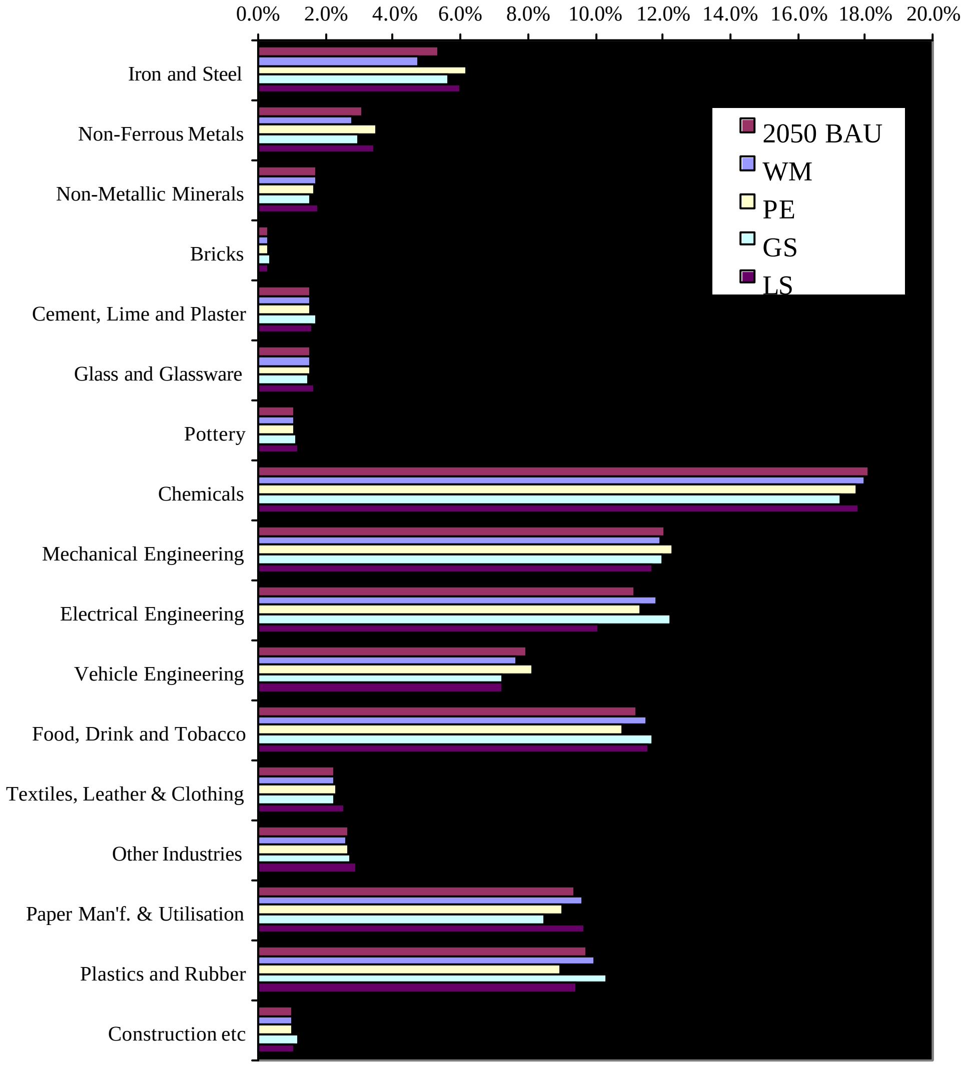
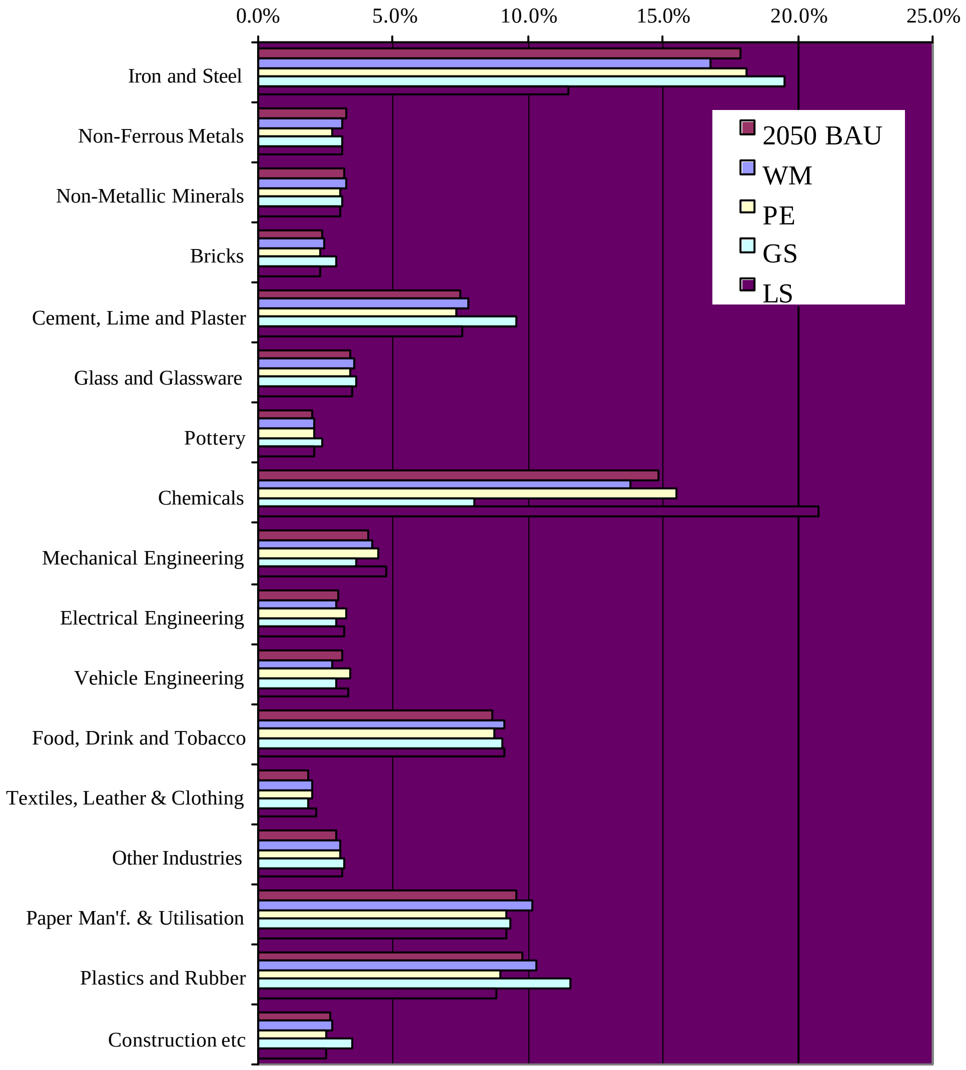


Figure 7 Sub-Sector Share of Industrial Fossil Fuels



6. Carbon Emissions Projections

Table 3 shows the equivalent carbon emissions for the energy demands in Table 2, on the assumption that electricity generation has a single, average emission factor equivalent to that in the DTI EP68 projections for 2020. In other words, no attempt has been made to distinguish between supply-side options in each of the scenarios.

	2050 Carbon Emissions (MtC)				
	BAU	WM	PE	GS	LS
Electricity	16.6	16.7	16.8	15.2	13.2
Fossil Fuel	10.8	10.3	11.6	8.2	10.4
Total	27.4	27.0	28.3	23.4	23.6

Table 3 Foresight Scenario Baseline Carbon Projections

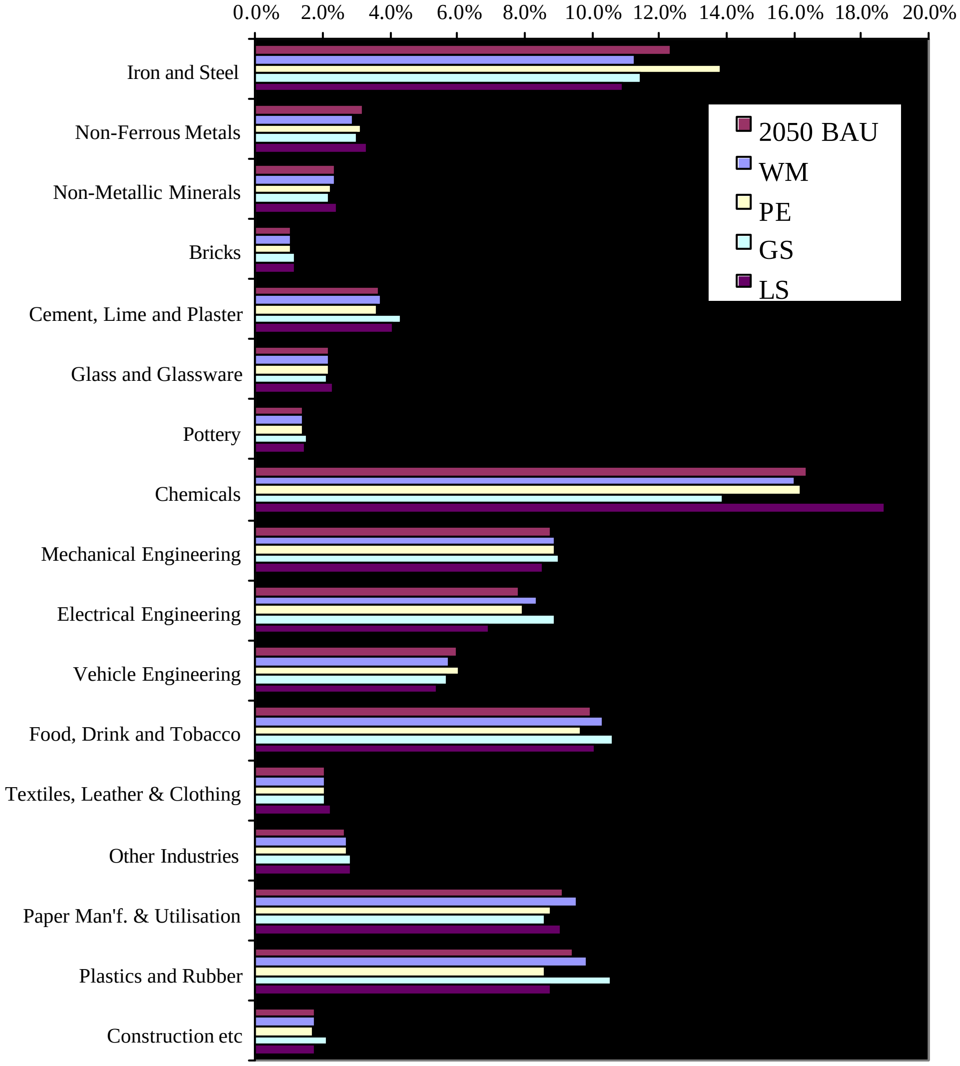
This also means that there is no switching to heat pumps or other electric technologies for servicing low grade heat demand (responsible for about 6-8 MtC in this set of baseline projections), as might be sensible if a lower carbon source of electricity were generally available in 2050. Thus the carbon totals for electricity give a lower-limit indication of the scope for further carbon abatement through supply-side changes such as low-carbon generation or carbon sequestration.

Fossil fuel demand is assumed to be met by natural gas wherever technically feasible, and there is no significant use of hydrogen for heating or steam-raising purposes. The most significant difference of detail affecting the overall emissions factor (C/E) is the reduction of iron ore using methane rather than coke under GS alone, which reduces the carbon intensity for this process by around 25%.

Figure 8 illustrates the approximate balance of carbon emissions that results from the energy projections and the set of assumptions made about fuel mix in each sub-sector.

Figure 8 Sub-Sector Share of Industrial Carbon Emissions

(assuming electricity emission factor as for 2020)



In general, the sub-sector emissions distribution in Figure 8 shows quite small differences between scenarios, with individual factors tending to cancel. The result is that under this interpretation of the baseline scenarios, the differences in industry shares tend to be more uniform than the inter-scenario differences in total industry emissions in Table 3 above. The altered balance between electricity and fossil fuel-derived emissions under GS is also important.

7. Scope for Further Emissions Reduction

The baseline scenario projections give an indication of the scale of emissions that might be expected from industry in 2050 without the UK (or other local political/economic group of countries) making any special effort to depart from general international practice. They do not include radical changes, such as general availability of zero-carbon electricity, or a hydrogen economy. Either of these would have similarly radical effects on the way that industry uses energy, and it would not simply be a case of plugging in new emission factors and counting the cost of the energy price changes. At company level, industries tend to follow best practice (local or international, according to the market) and comply with regulations, rather than set long term plans, so the whole balance of industrial production can be quite sensitive to any scenario changes which invoke ‘going it alone’ to any extent. Hence the less international PE – and particularly LS – scenarios are both more amenable to radical local changes, but also less stable and predictable as regards industrial energy demand.

R&D, and the wider aspects of innovation, are crucial if more rapid carbon abatement is desired, and the development resources needed by UK industry are liable to be greater, the further that the UK tries to take the lead. Whether this would gain a worthwhile long term competitive advantage can only be assessed in relative to particular market scenarios. For the long term, as for the medium, it could be argued that it is the level of development expertise and activity that is actually more important than guessing the right technologies to back at the research stage.

Because of the complexity of industrial energy use, there are probably only a few key technologies that are worthwhile examining in isolation at this stage; some of these are referred to below. Most of the additional scope is reliant on pushing investment decisions further and further in the direction of high-efficiency, low-carbon options, in the same sort of way that the Climate Change Programme is aiming to do, through a combination of price signals, agreements, regulation, support for research, and information programmes designed to change attitudes as well as to enable.

Technical and economic potential for energy efficiency improvements is conventionally expressed via cost-supply curves. For a 50-year forward look, however, cost-supply curves have a built-in time horizon that is too short, and they present too pessimistic a picture for long-term technologies still in the development stage. Because it is impossible to know which of these will be successfully introduced, one is limited to assuming that at whatever stage one reaches, there will always be a set of options offering further potential in the future. The rate of development of these options will depend on prospects for energy prices and emission taxes, and again the cost to UK industry will depend on how much of its new technology is already available on the international market, and what level of expertise exists to take the innovative processes to completion.

Hence it is proposed to develop a costing method built on the concept of a series of CCP-like programmes, of sufficient intensity to accelerate the process of technological change enough for the chosen target to come within reach at the appropriate time. i.e. following a new scenario path where the rate of change is increased even though the details are unknowable for more than a few years ahead at any one time. This is not a revolutionary concept, but merely an extension of currently deployed policy measures.

Costing of individual demand-side abatement technologies is difficult unless the context is fully defined, and simplified methods need to be applied. One would involve estimating the product price increase that would result from changing to a new technology, and working out what level of increased carbon tax[11] would be needed to make the switch commercially sensible. This should take into account all of the secondary effects (e.g. improvement in labour productivity), and the answers will need to be set against market conditions. Obviously in an international market it is difficult to achieve major changes in isolation unless the carbon tax is recycled to fully offset any cost increases, since they cannot easily be passed on to the customer. Such an approach would enable comparisons between abatement technologies in different industries, and – using a suitable linking model – to the cost of supply-side options. An example to be followed up is ironmaking, for which investments are very long term by industrial standards, and the industry has already made detailed costings – in terms of production costs per tonne – of a wide range of alternative technologies.

The projections for all of the baseline scenarios show that of the sector-specific technologies, those in the Basic Metals and Chemicals industries are the most important in carbon terms. There are thermodynamic limits to process efficiency which are relatively close in some cases – e.g. blast furnace technology and electrolysis. Taking the carbon out of ironmaking is the only way of reducing emissions (apart from sequestration). Electrolysis may take advantage of low carbon electricity, or be sidestepped by material substitution or increased recycling (e.g. of aluminium). In the Chemicals industry, many reactions require energy to drive them, but conversely many are exothermic. Process integration, whereby heat from one reaction is used to drive another, solves many problems and leading companies have already exploited the possibilities. A major prize still to be won is that of low energy separation techniques, especially of liquids for which distillation still uses a very high fraction of total energy use in the industry.

The scope for long term carbon abatement through Combined Heat & Power needs reappraising, since its effectiveness is strongly dependent on (a) the existence of heat loads (or combined heating and cooling), which are expected to be in general decline; and (b) the carbon intensity of centralised electricity generation, which will presumably improve by 2050. Present estimates of potential – around 15 GWe – were made in terms of cost-effectiveness to the installer under particular energy pricing

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[11] A rise in the price of energy would not necessarily achieve the desired result, e.g. a switch from coke to gas in ironmaking would need an effective increase in the relative cost of coke, rather than a general rise in all energy prices.

conditions, rather than with a view to saving carbon emissions. In particular, the use of low-carbon energy sources for CHP needs to be brought to the fore.

Annex 1: Sub-Sectoral High Grade Heat, Low Grade Heat and Electricity

(*Revised from previous IAG paper and extended)*

These notes cover the energy use in the manufacturing and construction industry sectors, and follow the RCEP report in using three main categories for demand: High Grade Heat (HGH), Electricity, and Low Grade Heat (LGH).

The intention is to review the areas in which significant process change or efficiency measures could improve end-use efficiency in these categories during the next 50 years, guided by the likely volume of demand in each of the relevant industry sectors. At present, the list is at an embryo stage, and the purpose is to identify areas for more detailed treatment.

High Grade Heat

Appendix E Table E.4 of the RCEP report has 16 GW HGH projected as the baseline demand for 2050, all of which is assumed to be delivered by natural gas.

Iron & Steel: Accounts for around 2/3 (10.2 GW) of current total industrial HGH demand. Mostly coke, in blast furnaces, with gas and some oil used for re-heating furnaces etc. The coke is used for its mechanical properties as well as energy and carbon content, and moving away from coke requires major re-investment in alternative process technology and plant. Several methane-based alternatives are already commercialised abroad, but the market economics are finely balanced.

- If the dominant fuel is changed to gas as assumed, then the energy requirement could be significantly less than 10.2 GW, which reflects current dominance of coke. If electricity use stayed the same, and rest were gas, then 10.2 becomes 8.0 for typical new technology.
- The fuel mix could go much further towards electricity if more steel scrap is utilised (currently the UK exports steel scrap), though there is a quality issue (high purity steels, e.g. for car body pressings, cannot easily be made from scrap). However, some alternative high grade steel processes do use electric melting in conjunction with methane reduction. Hence there is a need to maintain a distinction between fossil fuel and electricity demand in this sector. One need to look at a selection of scenarios, taking account of studies such as the IISI Energy Report and the USDOE OIT ‘Industry of the Future’ projects.
- 8 GW should be considered for carbon sequestration, since one integrated works is as large as the biggest power station. Therefore assume low carbon technology as for ESI either way – electric (CCGT) or direct gas.
- Is the timescale credible? Is the production level attainable? A possible scenario would be cut capacity to half of the current level, with the remaining half replaced with methane process by 2050. Depends strongly on markets (esp. enlarged EU).

Cement, Lime & Plaster: around 2 GW HGH at 2000 level.

- Gas kilns for cement are straightforward, if the price is right, and there is plenty of international experience. Waste burning, e.g. tyres and waste solvents, currently zero-rated for carbon but limited by environmental/politics sensitivities, could make a big difference to carbon emissions in the short to medium term, but these kinds of waste are unlikely to be regarded as a zero-carbon source in 2050.

- Each works has less than 7.5% of total production, i.e. < 150 MW. Carbon sequestration marginal for biggest plant might be feasible.
- Demand is quite likely to be similar in 2050, with efficiency options of at least 10%. Local production reduces transport costs.

Ceramics: around 1 GW HGH.

- Almost all gas already
- Demand is quite likely to be similar in 2050. Pottery import fraction significant.
- Efficiency options >20%

Glass: around 1 GW HGH.

- Almost all gas already
- Demand is quite likely to be similar in 2050, with increased utilisation and recycling. Significant fraction of imports.
- Efficiency options >20%, offset partly by recycling energy demand (?)

Engineering: around 0.6 ± 0.1 GW at current level.

- Continued structural change may reduce energy demand rapidly.
- No obstacle to gas
- Energy intensity changes dominated by structural change, as opposed to energy efficiency at process level.

Non-Ferrous Metals: around 0.5 GW

- Mostly gas for secondary melting/refining
- Increased recycling would use gas also
- Efficiency options >20% but likely to be offset by growth

Minerals: about 0.3 GW

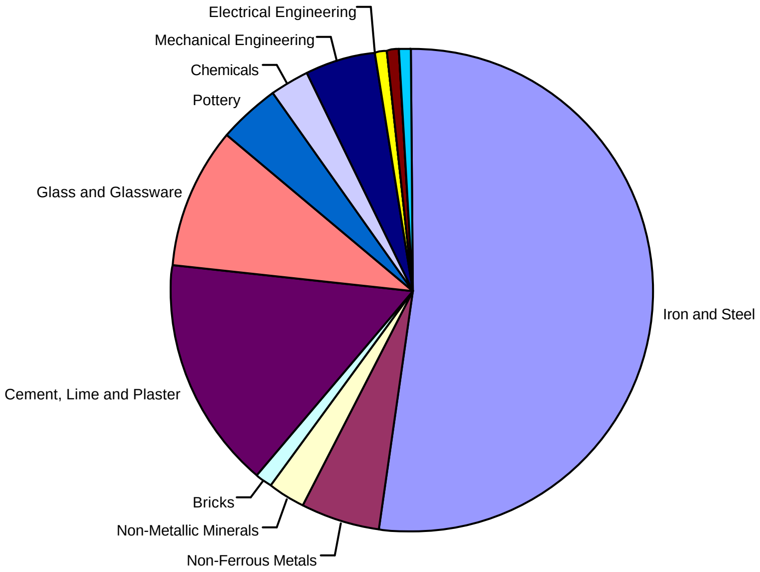
- Mostly gas
- Demand is quite likely to be similar in 2050.
- Efficiency options >20%

Other sectors – various with total < 1GW (?)

Rough totalling of the above gives 8 – 11 GW, or 35 – 45% reduction in fossil fuel energy demand for HGH. (Proportional reduction in carbon is considerably greater because of fuel switching, especially in I&S)

The BAU baseline projection in the main text corresponds to about 8 GW, divided between sub-sectors as in Figure A1. Iron & Steel dominates the picture, with over 50% of the requirement, even though production capacity is projected to fall to about half of the current level. The Iron & Steel fraction of carbon emissions derived from high grade heat is even higher (~60%) if blast furnace technology is retained, as assumed for BAU.

Figure A1
2050 BAU Projections for Sub-Sector Distribution of High Grade Heat
(labels have been omitted for contributions of 1% or less)



Electricity

Industrial electricity use currently accounts for around 1/3 of total UK consumption – around 11GW – and is growing at about 170 MW per year in absolute terms. The industry fraction of total electricity demand is also growing steadily, though not as fast as service sector demand. The RCEP assumption of 32 GW in 2050 under Scenario 1 takes no account of ongoing trends, and appears to be an underestimate. Industrial demand alone could grow from its current 11 GW to over 20 GW if there are no major changes in the pattern of use. The breakdown between sectors would depend on relative growth, and in the following notes the figures assumed are intended simply to highlight the main issues. Together they amount to a bottom-up estimate of 15 – 19 GW for 2050, as compared with the 11 GW implicit in the RCEP Scenario 1, and around 20 GW for the BAU reference scenario described in the main text above.

N.B. The small amount of electricity used for generating low grade heat has not yet been accounted for explicitly.

Iron & Steel: Currently accounts for about 10% of industrial electricity demand, about half of which is used in electric arc furnaces (EAFs). EAFs produce a range of steels from scrap, so most of their output consists of alloys for which ‘tramp’ elements in the scrap are not critical. Steels for high quality pressings (e.g. car bodies and cans) currently require iron of a purity that at present is only achieved by reduction of ore in blast furnaces. Local production is most likely for the lowest grades, e.g. re-inforcing bars, because of transport costs. 2050 consumption is very uncertain, due to international market factors. The choice of future technology may possibly be dependent on the carbon intensity of electricity generation, as well as relative prices of electricity and fossil fuels, and the volume of EAF melting could increase under some circumstances. Energy efficiency opportunities (e.g. tower furnaces to maximise waste heat recovery in EAFs) offer 10% savings but are only applicable to new plant. With no increase in electric melting within the iron-making process, electricity demand could be of the order of 0.5 – 0.7 GW.

Non-Ferrous Metals: Currently using around 7% of industrial demand, by far the most important process is primary aluminium production. UK plant is currently holding its own in world markets, which are growing. Energy efficiency improvements are very limited for the current process, and viable alternatives have yet to be established, mainly because of materials problems. Across the sector as a whole, energy efficiency is unlikely to save more than 5% unless the primary aluminium smelting process is replaced. Consumption could be of the order of 0.7 – 1.0 GW depending on growth, although there is a strong probability that if there were increased costs attached to carbon emissions, primary smelting would move out of the UK to locations with zero carbon electricity.

Cement. Minerals, Ceramics & Glass: Electricity consumption in these high temperature industries is relatively small, and with a few minor exceptions there is little scope for major reductions through improved end-use efficiency. Total consumption in 2050 could be around 0.7 – 1.0 GW.

Chemicals: Using around 20% of current consumption (2.3 GW), this sector is among the most important to understand, since demand is increasing at around 1% per year, and there are major structural changes still taking place in the industry. Roughly half of the electricity is used in electrolytic processes, e.g. chlor-alkali, most of which are already running at close to their optimum performance. Here, market factors affecting demand for basic chemicals are much more important than end-use efficiency, and it is likely that chlorine demand will fall for environmental reasons over this timescale. Otherwise, chemical processes are not very electricity-intensive, and the consumption is mainly in motors and drives (for pumps etc and refrigeration equipment). This sector is very energy conscious, and efficiency opportunities are being taken up. However, growth is almost certain to outstrip technological opportunities for end-use demand reduction. Baseline consumption in 2050 is likely to be in the range 3 – 4 GW.

Engineering: Together, the engineering sectors account for around 22% of industrial consumption, making them the largest user of electricity. They also have the highest projected growth in demand, of nearly 2% per year until 2010. Motors & drives and air compressors are major consumers, but so also are IT equipment and building services including lighting and air conditioning. Major structural changes are still taking place, with the electronics/electrical subsectors growing fastest. Most electricity-consuming engineering processes, other than heat treatment, are not particularly energy intensive, and energy efficiency is not high priority, nor are there major sector-specific end-use efficiency measures other than general building services management. Rapid technological evolution leads to new process plant starting up at relatively low utilisation and moving steadily towards maximum capacity; this gives an impression of improving efficiency at company level, but is potentially misleading for the sector as a whole. Baseline consumption in 2050 is likely to be 4 – 6 GW, i.e. around double the current demand.

Food & Drink: At around 10% of industrial electricity demand, this sector's consumption is growing at around 1% per year, and represents an increasing fraction of total sector energy demand. Motors and drives for pumps and refrigeration make up the majority of electricity use, though building services are also significant. Process equipment tends to be adapted rather than replaced wholesale. Efficiency opportunities are mainly in alternative refrigeration technologies (e.g. absorption chilling in association with CHP). A major issue for the future is what fraction of food and drink products will require refrigeration. Baseline consumption in 2050 is likely to be of the order of 2 GW.

Plastics & Rubber: Electricity demand in this sector is currently 8% of industrial demand, and growing at around 1% per year. The vast majority of consumption is associated with motors and drives, and air compressors, and the same considerations apply as for general engineering. Process developments over the next 50 years are likely to be driven by changing materials. Projected baseline demand in 2050 could be of the order of 1 GW.

Paper Manufacture and Printing: Consuming around 11% of the industry total, electricity use in this sector is increasing at around 3% per year. Most of this increase appears to be in the printing industry, but further analysis is needed, with a distinction between paper manufacture and printing. Current projections would suggest a 2050 consumption of over 2 GW.

Textiles and Other industries: Together, the remaining sectors represent around 6% of industrial demand, and consumption appears static. Electrical energy efficiency is not a high priority, and general engineering and building services considerations apply. Projected consumption could be around 0.4 – 0.8 GW.

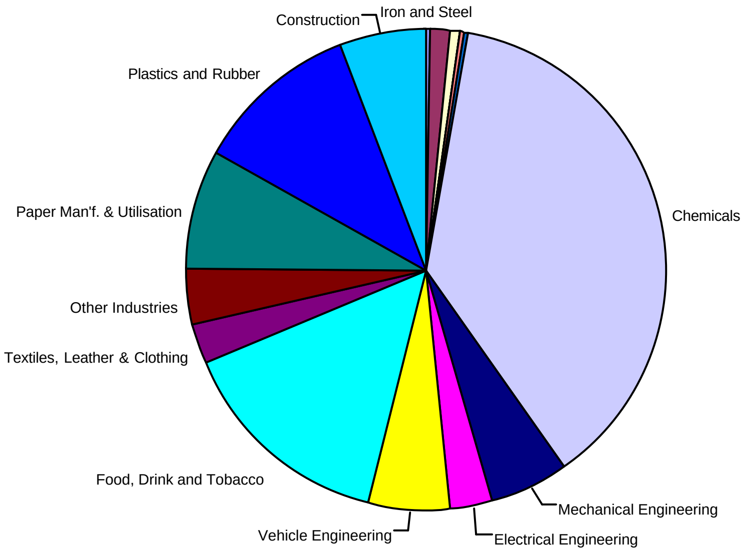
Low Grade Heat

The RCEP Scenario 1 implication for industrial LGH is around 21 GW. However, on the basis of current trends this is likely to be an over-estimate, tending to balance out the under-estimate of electricity demand noted above. Projections of industrial fossil fuel demand are very difficult since there have been major changes in the past 20 years, and the pattern is not settled. However, long term trends, minus the likely demand for HGH above, suggest a figure in the range 10 – 15 GW in 2050 overall. Gas firing already accounts for the majority of LGH demand, and there is relatively little scope for carbon saving via fuel switching. The BAU projection described in the main text above indicates approximately 14 GW of LGH, distributed between sub-sectors as in Figure A2.

Figure A2

2050 BAU Projections for Sub-Sector Distribution of Low Grade Heat

(labels have been omitted for contributions of 1% or less)



Overall, an increasing fraction of industrial LGH is concerned with building services; space heating and hot water. Building insulation – generally the most potent measure for improving space heating efficiency – is problematic for many existing industrial buildings, especially those which house energy-intensive processes. However, turnover of industrial building stock is relatively rapid, and improved building technology (and regulations) should have a significant effect [to be investigated].

Many LGH-requiring processes span several industry sectors. The most important of these is drying, and the critical end-use technology is waste heat recovery. On the supply side, CHP has a large part to play in the medium term. The most important sector-specific technology is separation, in the Chemicals sector. A major technological change which has been on the horizon for some time is membrane separation, to displace distillation, but materials-related problems are still preventing large-scale commercialisation. Further improvements to distillation efficiency are still possible and economically viable, however.

N.B. The small amount of electricity used for generating low grade heat has not yet been accounted for explicitly.

Status of individual sectors: [To be developed. Chemicals (projected ~35% total LGH), Food & Drink (~13%), Plastics & Rubber (~10%) and Paper Manufacture (~8%) are by far the most important sectors as regards process requirements for LGH.]