‘Peak Stuff’

Did the UK reach a maximum use of material resources in the early part of the last decade? [1]

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Empirical evidence presented in this paper supports a hypothesis that the UK began to reduce its consumption of physical resources in the early years of the last decade, well before the economic slowdown that started in 2008. This conclusion applies to a wide variety of different physical goods, for example water, building materials and paper and includes the impact of items imported from overseas. Both the weight of goods entering the economy and the amounts finally ending up as waste probably began to fall from sometime between 2001 and 2003.[2] Summary data is available on the last page of this document.

If correct, this finding is important. It suggests that economic growth in a mature economy does not necessarily increase the pressure on the world’s reserves of natural resources and on its physical environment. An advanced country *may* be able to decouple economic growth and increasing volumes of material goods consumed. A sustainable economy does not *necessarily* have to be a no-growth economy.

The problem

Is continued economic growth possible without increasing the strains on the global environment? This question has been debated for several decades. Pessimists have pointed to the continuing increase in the world’s use of physical resources, such as fossil fuels and fresh water, as the size of the global economy grows. They believe that the world needs to recognise that growth, at least as conventionally defined by economists, necessarily imposes greater and greater pressures on the world’s ecology.[3] The potential problems are numerous; more burning of fossil fuels means increased risk of dangerous climate change, the strains on fresh water supplies will grow, fertiliser use will cause increased marine pollution and the extraction of ores and minerals will cause major environmental problems on land.

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[1] Mark Lynas and Mike Berners-Lee provided extremely helpful comments on a first draft of this paper. Duncan Clark gave very detailed feedback indeed. I am very grateful to them all. Errors remain mine. Any further comments on this article would be very much appreciated.

[2] The decline between 2003 and 2007 occurred at the same time as UK population rose by about 2.4%. Source: ONS population estimates.

[3] In his powerful book *Prosperity Without Growth,* Tim Jackson makes the pessimistic case particularly well in the chapter entitled The Myth of Decoupling.

More sanguine commentators have hypothesised that beyond a certain point economic growth requires smaller amounts of material input: richer societies should be able to impose a lesser strain on the global ecosystem as they become more efficient in their use of fuels, minerals and the biological materials grown on the earth's surface. Taken in the round, technological change tends to reduce the weight of raw materials needed to provide a useful good or service. The optimists claim that continued economic growth is wholly compatible with ecological stability because richer societies will actually need fewer material inputs and will switch to economic activities based on the use of information and the provision of services. The rapid economic growth of China and other transition economies is causing severe environmental stresses on land, water and in the atmosphere. But once these countries have reached a certain level of development, the optimists say, their impact on the world's ecology will tend to diminish.[4] They argue therefore that faster growth in China is to be welcomed.

There are few more important issues to resolve than whether continued economic growth and ecological stability are compatible. Empirical investigations into this topic have tended to produce inconclusive results that suggest that rich economies have, at best, partially decoupled economic growth from increasing use of material resources. The volume of physical inputs used by the economy has tended to rise, but at a much slower rate than economic growth. In other words, there has been some gain in efficiency, but not enough to reduce the absolute level of resources used. A country might, for example, grow at an average of 2% per year but the fossil fuels necessary to sustain the economy might typically only grow at 1%. This is usually called '*relative* decoupling'. The evidence presented here is compatible with a much stronger hypothesis that the UK may have begun a process of *absolute* decoupling in which resource use falls even in periods of growth. In times of recession, the decline will be faster still.

The simple model of an economy expressed in physical terms

Government statisticians regularly measure the physical resources used by a country. In the UK, these measurements produce a series called the Material Flow Accounts. First, the statisticians estimate the three main sources of material resources used to sustain the economy: biomass, minerals and fossil fuels.

- **Biomass** The economy produces agricultural harvest that provides food to the population and fibres for textiles. Second, animals graze the fields, eating grass and other biomass that they turn into meat and other useful material. Third, timber is collected for fuel and for other uses. Lastly, fish is collected from the seas and rivers for food.
- **Minerals** Ores are used for processing into metals and other substances. Clay makes bricks and other building materials as well as pottery and raw materials for paper and other products. Sand and gravel, stone and other minerals are used for construction of buildings and road.
- **Fossil fuels** Fossil fuels are used for burning for heat and electricity as well as providing the raw materials for plastics and chemical products.

Each of these three types of input is processed to deliver value to the human population and eventually becomes waste.

[4] The hypothesis that the environmental impact of a country rises sharply as its national income increases but then tends to fall once a high GDP has been reached is often called 'the environmental Kuznets curve' after the economist Simon Kuznets who pioneered national economic accounting.

Biomass

Most biomass employed as food is returned to the earth's surface. Biomass, both fish and land harvest, is eaten and excreted by animals and humans. Human waste in advanced societies generally ends up as sewage sludge, which is typically returned to the soil by application as a fertiliser. Waste food in advanced economies is usually collected and put in landfill (where it will usually turn into methane) or it is composted.

Biomass used for fibres and textiles, such as wool, linen or cotton, will generally become municipal waste. (Some clothing is reused, but it still eventually ends up in landfill or compost).

Excluding small amounts of ash, timber that is used for fuel returns to the atmosphere, principally as CO2. More UK timber is turned into paper and other products based on pulp. These products will generally end up in municipal waste. Other wood is used in construction, where it will often be stored for a long period, perhaps hundreds of years, but will eventually rot or be burned and become carbon dioxide.

Minerals

Minerals are refined to make metals and other products. The waste from mining and industrial processing used to be placed in landfill but increasing amounts are now reused. The major end-products, such as steel and aluminium, can be indefinitely recycled although a large portion is still added to waste depositories. Stone, sand and gravel are employed in construction. Eventually, most building materials end up as inert waste, and are recycled or put in landfill, though the delay can be hundreds of years.

Fossil fuels

Fossil fuels will generally be burnt creating carbon dioxide, which is added to the atmosphere but may in future be stored underground as a result of carbon capture.

So the human use of fuels, minerals and biomass to sustain our living standards result in some clear outcomes. Biomass will generally be returned to the soil or added to the atmosphere in the form of CO2, with some small portion ending up as municipal waste. Mineral ores tailings will be returned to the ground while the useful portion of the ore – such as a metal – will either be in a recycling loop or be disposed of as waste. Fossil fuels end up in the atmosphere. The simplicity of these routes helps us assess whether the impact of a modern economy on the global sea, land and atmosphere is rising or falling. Everything we use has to come from one of the three groups – biomass, minerals and fossil fuels – and has to be eventually added to the atmosphere, be returned to the ground, or live on in endless recycling loops. If we can measure the weight of what we extract from the ground and what we eventually put back as waste then we can estimate whether the necessary impact of economic growth is to impose extra strains on the earth's resources.

The UK's material flow accounts

These accounts are prepared to the high standards of the UK's Office of National Statistics (ONS). They are necessarily imprecise but provide a good guide to the weight of resources used by the British economy.

These accounts offer three principal indices.

- **Total Domestic Extraction (TDE).** This measures the weight of biomass, minerals and fossil fuels taken from the ground in the UK.
- The UK imports biomass, minerals and fossil fuels. The second index is called **Direct Material Consumption (DMR)**, which adds imports and subtracts exports from Total Domestic Extraction.
- Goods imported into the UK are made using resources of biomass, minerals and fossil fuels in their country of origin. The third measure includes estimates of the materials employed in other countries to make UK imports. This is called **Total Material Requirement (TMR)**.

These three figures represent estimates of the total inputs into the UK's material standard of living. The important point is this: if economic growth implies increased use of physical resources then we should see increased material inputs when the economy is growing, as it did with remarkable constancy during the fifteen years from 1993 to 2007.

Total Domestic Extraction, the measure of the weight of resources of biomass, minerals and fossil fuels extracted in the UK, peaked in 1988 and by 2007, the year of the end of the boom, had fallen to 74% of its 1988 figure. The obvious explanation is that the UK now imports a larger fraction of its total consumption of physical goods, and that extraction elsewhere in the world is increasing as a result. But the two other measures – Direct Material Consumption and Total Material Requirement – may also have peaked before growth was interrupted in 2007 and they incorporate estimates of resource use in foreign countries to make the UK's imports. Direct Material Consumption (DMC which is Total Domestic Extraction less exports plus imports) peaked in 1973 at 838 million tonnes and slid erratically to 700 million tonnes in 2001. Total Material Requirement (TMR), which includes estimates of the resources used outside the UK to make goods that are then imported into this country, reached an absolute peak of 2174 million tonnes in 2001. It is not entirely clear that the trend is strongly downwards from this point but by 2007, this figure was 2091 million tonnes.

By 2007, the DMC and TMR measures had fallen to 96-97% of their 2001 figure. One conclusion is that material use in the UK, and indirectly through its imports, was falling in absolute terms during the half decade prior to the economic downturn. This implies some absolute decoupling of growth and physical extraction, and hence a reduction in ecological pressure.

Unsurprisingly, the fall in resource use became more rapid in 2008 and 2009. The year 2009 saw a recorded Total Material Requirement lower than all the years of the past decades with the exception of 1981. The recent recession has been severe but UK GDP is still well over twice the level of 1970. The Total Material Requirement then (1768 million tonnes) was higher than the 1755 million tonnes estimated for 2009. This point bears repeating: if the ONS statistics are accurate, the economic growth in the UK over the last generation has not resulted in any increase whatsoever in direct environmental pressure. This is not an argument for complacency: climate change, for example, arises from the *stock* of burned fossil fuels and biomass transferred to the atmosphere in the form of CO2 so each year the problem becomes slightly worse. Nevertheless, the environmental movement's belief that growth makes all ecological problems worse may need to be re-examined.

Table 1

Changes in levels of material inputs into the UK economy

Measure (million tonnes)	TDE	DMC	TMR
2001	663	700	2174
2007	557	679	2091
2009	458	566	1755
2007 as percentage of 2001	84%	97%	96%
2009 as percentage of 2001	69%	81%	81%

Source: Material Flow Accounts for the United Kingdom, 1970 to 2009, Office of National Statistics (ONS)

Other measures of materials use

Thus far, this paper has only commented on the decline in the crude measures of the weight of physical material used as raw inputs into the economy. Does other data on the eventual use of this material as it flows through the economy as useful goods, ending up recycled or as waste, support the theory that the UK has seen the beginnings of decoupling of economic growth and resource use? In the following pages I investigate whether the things we actually use in the UK – goods such as paper, cement, fertiliser, food, cars – have also seen a reduction in the physical volumes entering the economy. Then we'll go on to look at measures of final waste – such as greenhouse gases and domestic rubbish collections – also show a reduction since the earlier part of the last decade.

This approach is described in the simple graphic below. The raw materials powering the economy are shown on the left. These get processed into the useful things in the middle column. As they are consumed or wear out, these goods and services get turned into waste on the right hand side. Increasing volumes of the goods in the middle column are put into a recycling loop that enables them to be reused. (An R marks the goods in which recycling is already well established). This will reduce the amount flowing into the waste column and also eventually cut the use of raw materials needed to make new goods. An economy in which everything was recycled (except food) would require much lower levels of new inputs from the left hand column.

This paper will provide data on the eight goods and services in the middle column, suggesting that in at least seven cases production peaked at some point well before the end of the economic upswing in 2007. In addition the data shows that water use started falling well before the peak of the economic cycle. Not all the numbers go back in time as far as we might like, and some have problems of reliability. But the overall results are clear. The numbers on waste disposal show similarly unambiguous results. The evidence is that the UK hit peak consumption around 2001 to 2003.

Why did I choose the goods and services featured in the second column, and omit other important products such as ferrous metals and plastics?

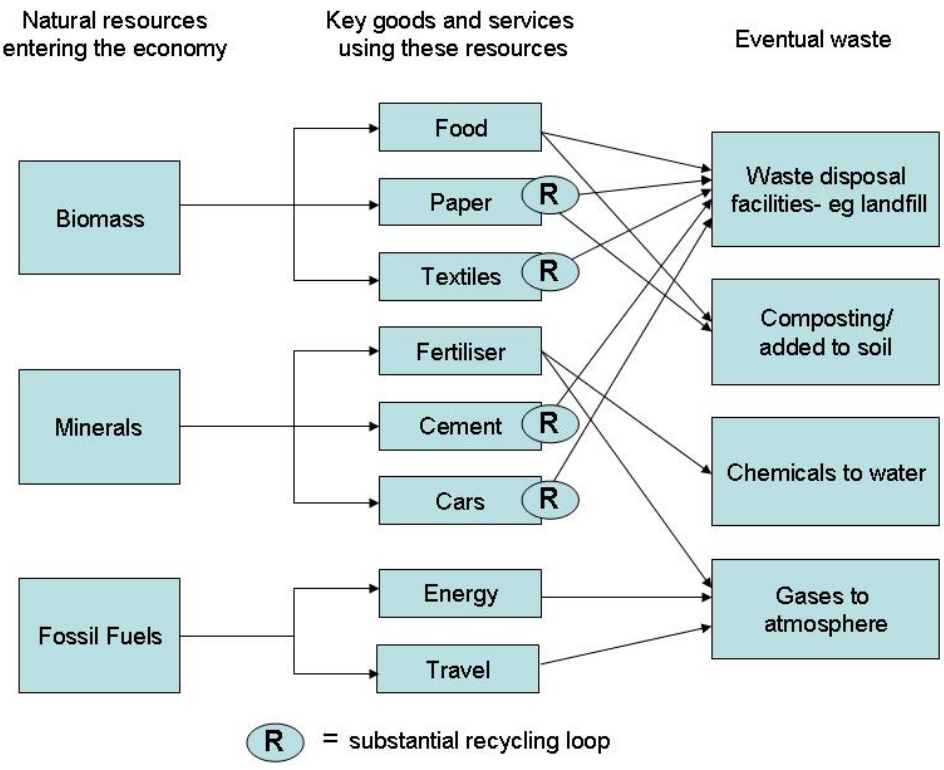
- The items in the column were chosen because they create much of the ecological impact of modern life. Food production, for example, is often said to be responsible for about 20% of the UK's domestic production of greenhouse gases. Fertilisers are the major source of nitrogen pollution in fresh and sea water. Motor vehicles are the single largest item (by weight and by embedded energy) bought by households. More details about the importance of each item are

provided in the individual sections that discuss the growth and decline of production volumes. Other researchers will want to explore whether the patterns found in this paper of decoupling of growth and resource use apply to all major groups of goods in the economy.

- The important items that are not in the list are omitted either because I could not find a source of reliable data or because a large portion of the production or consumption of the product is disguised in other products. This is true for many metals and for plastic. Take steel, for example. There is good information on both the UK production of steel and of imports. But it is impossible to estimate how much of the country's use of new steel occurs in the form of finished goods made from steel that are imported into the UK. If a washing machine is made in the UK from steel made either in the country or imported from elsewhere, then steel production or import data gives an estimate of UK use. But if the washing machine itself is imported we do not have this information.

Chart 1

An illustrative chart showing some of the most important flows of materials through the economy

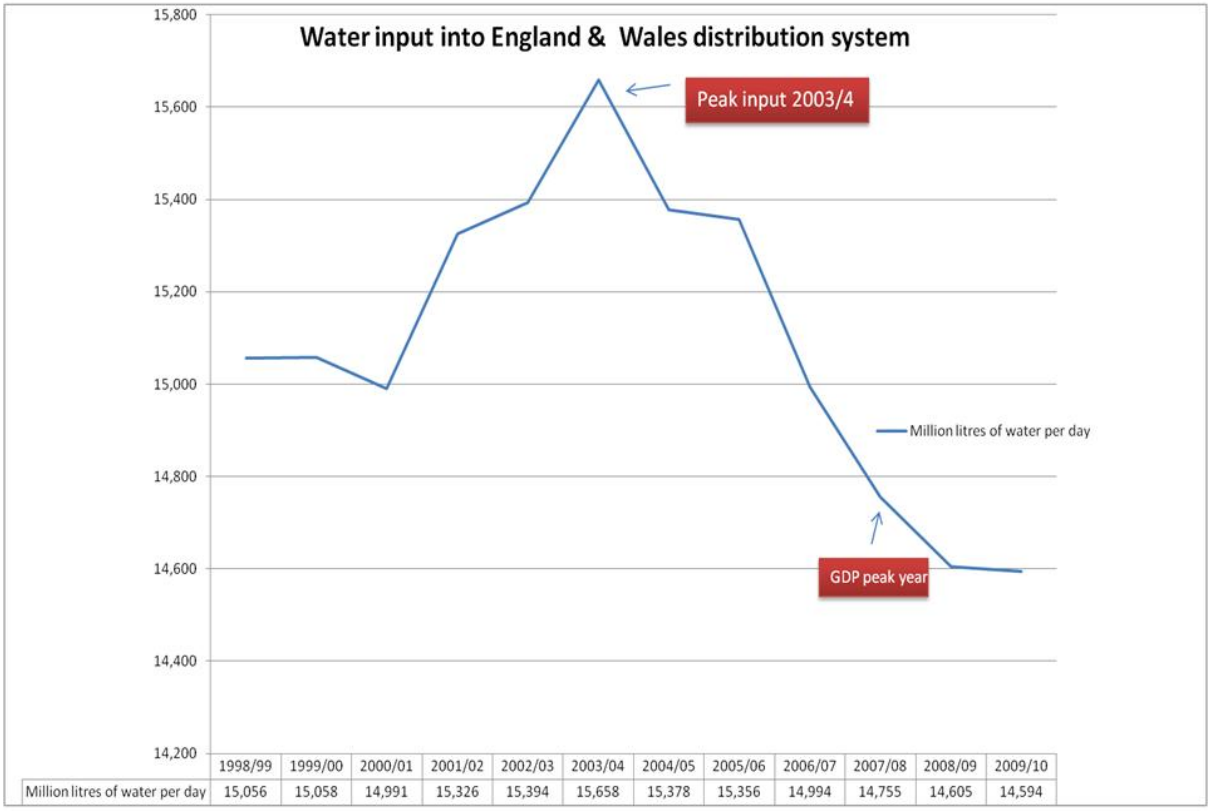


One major input – clean fresh water – is omitted from this chart, and from the UK's national material flow accounts although it is an input in the same way that timber, food or iron ore is. Global fresh water availability is limited and over-use of this resource produces environmental stress. Inland lakes, such as the Aral Sea, are substantially over-used and their volume is often falling fast, affecting the local ecology and reducing the water resources available for people, animals, agriculture and industry.

1) Water use in the UK

The amount of fresh water put into the water distribution system by the water companies of England and Wales peaked in 2003/4 (see chart 2).[5] By 2007/8, the volume had fallen to 96% of peak and by 2009/10 (the latest year available) the amount had gone down to 93%.

Chart 2



	1998/99	1999/00	2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10
Million litres of water per day	15,056	15,058	14,991	15,326	15,394	15,658	15,378	15,356	14,994	14,755	14,605	14,594

Source: Ofwat, figures from the annual Security of Supply report

The raw figure needs to be supplemented by two further indices.

- Industrial use may have fallen because the UK is losing manufacturing activities. So we also need to assess whether household use is declining. The UK's increasing number of people and rising household formation, couple with a concomitant fall in average household size, should introduce an upward bias into water use. (Two households with one person in each typically consume more water than one household with two people).
- The decline in the volume of water needing to be put into the pipes may reflect decreasing losses through leakage. The UK's water regulator has put increasing pressure on the water companies to decrease the percentage of water put into distribution system that leaks from pipes before reaching consumers.

[5] The data on water use is taken from yearly Ofwat reports entitled 'Security of supply, leakage and the efficient use of water' and 'Service and delivery' from 2007/8.

First, household use. The average consumption in a typical household peaked in 2003/4 and fell to 96% by 2007/8 and decreased a further 1% by 2009/10. This is a reversal of the strong upward trend from 1998/9: 2003/4 household consumption was 7% up on the figure for that year.

Second, is overall reduction in water delivered into the distribution system by the water companies an artefact arising from lower leakage losses? No, the total amount of fresh water used by customers (that is, still in the pipes by the time the water arrived at the point of use) fell to 96% of its 2003/4 figure by 2007/8.

Two further questions about the core finding are relevant. 2003/4 was a dry year, meaning that the water usage in that period may have been inflated by the watering of gardens and increased irrigation. This point can be rebutted by showing that although the 2003/4 peak may have been slightly higher than otherwise would have been the case, the pattern of moderately rapid increases in water use up to that date, followed by clear decline thereafter leaves little doubt that water use did reach a genuine maximum in that year.

Lastly, it is worth noting the impact of charging for domestic water. Increasing numbers of UK households now pay a bill based on the amount of water used, rather than a charge derived from the size of the house. The move to billing customers from meter readings undoubtedly affects the average consumption. But disaggregated data that splits households into those metered and those unmetered groups also shows that both groups had peak usage in 2003/4 and have declined since. As we might expect, the fall is faster among metered households. The water companies in England and Wales are committed to reducing household use still further and publicly expect falls of nearly 20% by 2030. The amount of water used in the UK will almost certainly continue to fall substantially from its 2003/4 peak.

This isn't the end of the story. UK imports also contain large amounts of embedded water – think of the irrigation water in Mediterranean fruits, cotton from central Asia or the water used in making steel for imported cars. Any conclusion that the UK's total need is falling must also depend on declining volumes of water 'embedded' in imports arriving in the country.

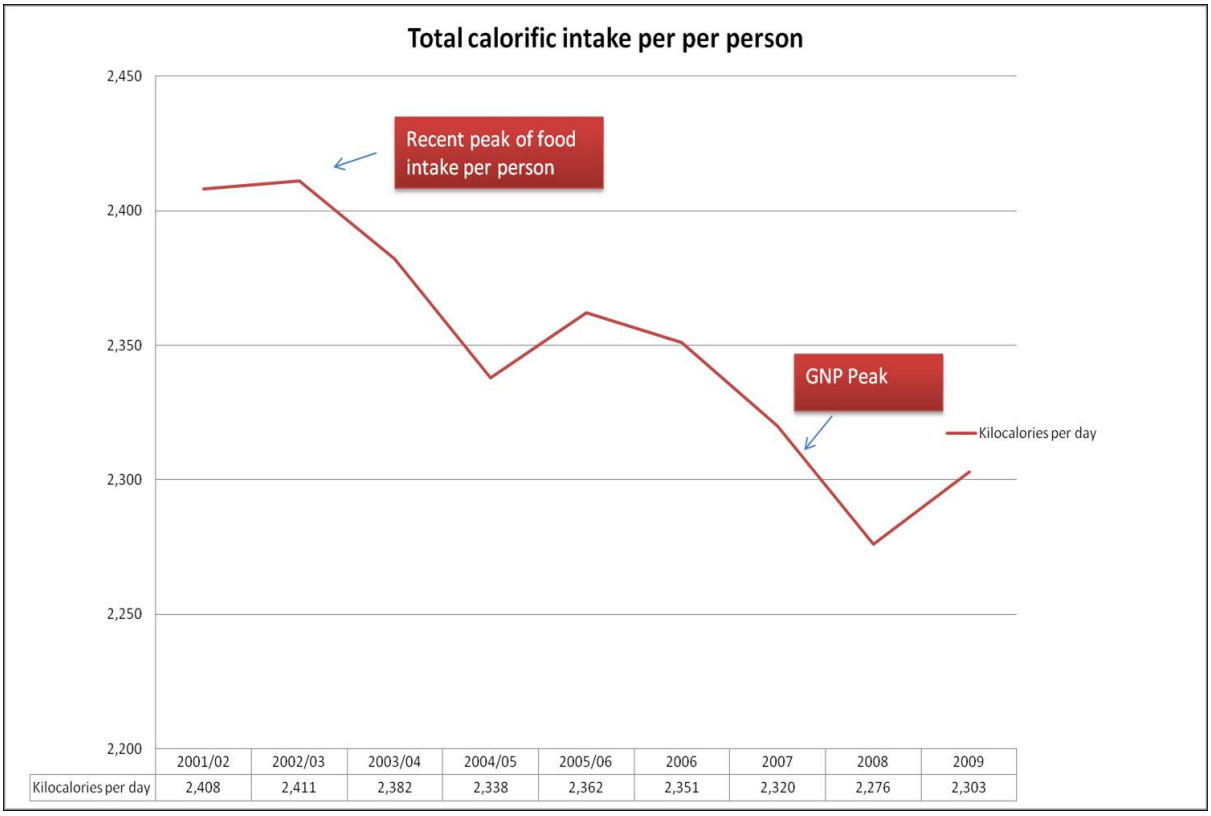
2) Food

Despite the growing amounts of obesity in the UK population, the average food intake, measured in terms of calories (actually kilocalories or kcal) has been falling for several decades, probably since the 1960's. An old data series that records the food intake of UK individuals but which excludes alcohol, meals out, soft drinks and confectionery, offers a typical calorie figure of 2,534 in 1974, falling as low as 2,058 by 1990. People nevertheless weighed less because they took more exercise and lived at lower temperatures during winter, which tended to keep their base metabolic rate at higher levels than today. (A calorie is a unit of energy as is, say, a joule or a kilowatt hour).

More up-to-date work includes calorie consumption from all sources (excluding pharmaceutical drugs).[6] The key data series goes back to 2001/2 and shows UK calorie intake on a downward trend. Economic growth in the period did not result in more calories being consumed. 2007 calorie intake per person was 96% of the levels at the beginning of the decade.

[6] The data on food is taken from the yearly National Statistics publication Family Food.

Chart 3



	2001/02	2002/03	2003/04	2004/05	2005/06	2006	2007	2008	2009
Kilocalories per day	2,408	2,411	2,382	2,338	2,362	2,351	2,320	2,276	2,303

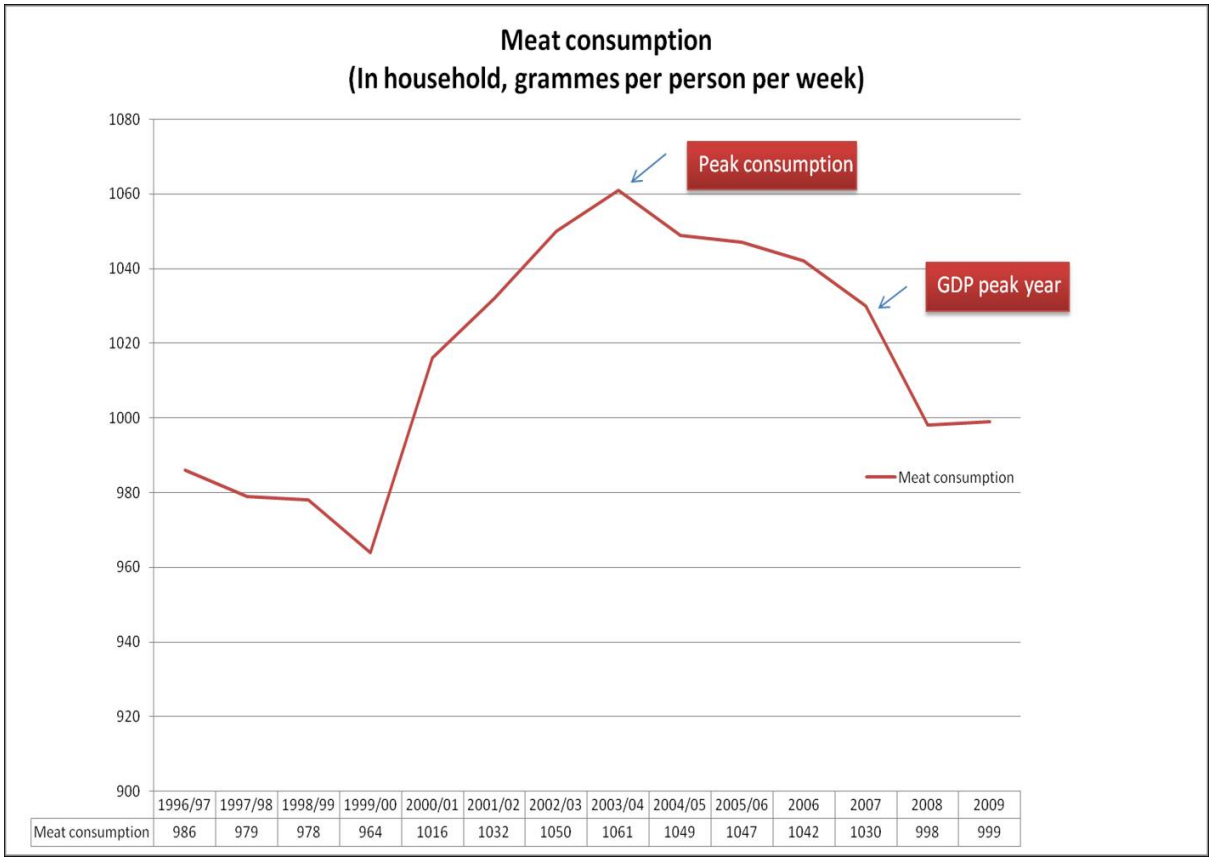
Source: Office of National Statistics, Family Food. Data is taken from various years and has been adjusted to ensure consistency from year to year as to what is included.

These numbers suggest that the amount of food used by the average person in the UK is tending to fall and that the decline is quite rapid. The average number of calories consumed by a person in the UK is one indication of the ecological stress imposed by the food production process from field to plate. Less food means less land under cultivation, lower levels of fertiliser application and less energy used to harvest and process the raw materials. As with water, at first sight the UK seems to have decoupled economic growth from material consumption.

To make this point with more certainty we need to introduce some finer analysis. Some crops require very limited amounts of energy, fertiliser and other inputs in order to grow. Organically produced oats might be in this category. At the other end of the spectrum, most meats cause substantial ecological loads. A piece of meat delivering 1,000 calories might have required ten times this amount of energy to produce, as well as substantial amounts of methane, a potent global warming gas. The implication is this: if the UK population reduced its calorie intake, but much more of this input came from sources that themselves imposed high environmental and energy loads, the UK would not actually have reached 'peak food'.

I have not found good data on the percentage of total calories that come from meat. But information is available on the grammes of meat typically eaten at home each week by people in the UK. This number appears to have peaked in 2003/4 at 1061 grammes falling to 1030 grammes by 2007, a reduction of 3%.[7]

Chart 4



	1996/97	1997/98	1998/99	1999/00	2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	2006	2007	2008	2009
Meat consumption	986	979	978	964	1016	1032	1050	1061	1049	1047	1042	1030	998	999

The amount of meat consumed out of the home has fallen faster. The average person ate 97 grammes out in 2003/4 and this had fallen to 77 grammes a week by 2007, a reduction of 20%.

Some researchers have pointed out the importance of also assessing the amount of food remaining unused and therefore wasted. Surveys have suggested a figure of 20% or more of total food purchases. To affect the conclusion that food volumes are going down, the wastage rate of food would have to be rising to compensate for declines in calorie intakes. Local government data actually suggest that the amount of food in household waste is falling, implying that the overall conclusion that total food inputs into the British economy are likely to be falling is a robust one.

3) Paper and other goods principally made from wood pulp

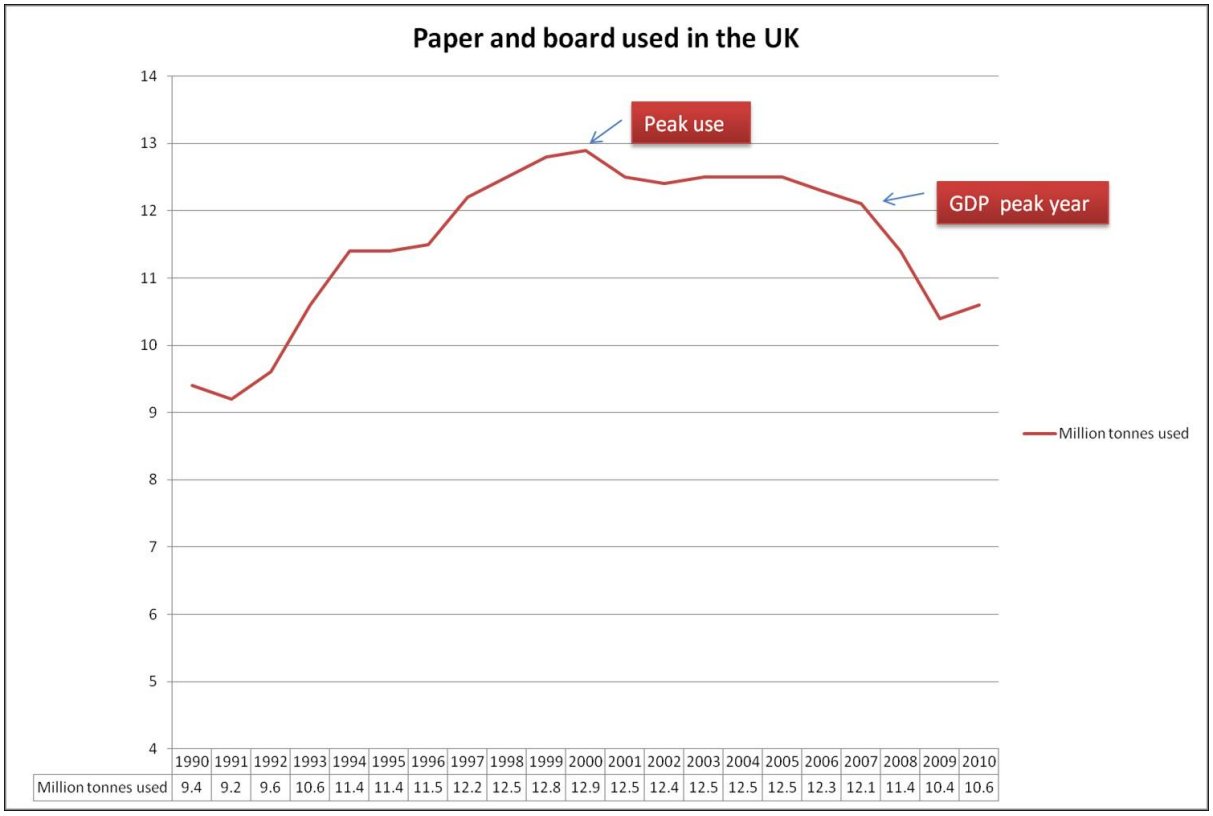
Paper is another important cause of ecological stress. Paper-making uses biomass that might otherwise be used for fuel. Paper-making uses substantial amounts of chemical inputs and the local pollution around plants is sometimes severe because of the effluents put into local watercourses.

[7] It should be noted that this figure is only slightly larger than the population increase in the period. Therefore the UK's total consumption of meat will only have declined by a small amount in this period.

The energy requirement to make paper is very substantial and although many plants use renewable sources, this electricity could have been used to substitute for fossil fuels rather than making paper. Although less than half of paper consumed in the UK is made in the country, paper-making still uses energy equivalent to 5% of the UK's total electricity use. Along with food, metals, chemicals and cement, paper-making is one of the most important contributors to the UK's carbon footprint.

Consumption (not production) of paper and board reached a peak of 12.9 million tonnes in 2001. It fell 6% to 12.1 m tonnes by 2007 and has since shrunk to just over 10m tonnes, levels that were last seen in the mid nineties.

Chart 5



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Million tonnes used	9.4	9.2	9.6	10.6	11.4	11.4	11.5	12.2	12.5	12.8	12.9	12.5	12.4	12.5	12.5	12.5	12.3	12.1	11.4	10.4	10.6

Source: Confederation of Paper Industries, Industry Facts 2010. Available at www.corrugated.org.uk

The reduction in paper and board use arises from improvements in efficiency (including reducing the weight of cardboard used in packaging, for example) and from increasing digitalisation of information that might otherwise have been stored on paper. As the circulation of newspapers falls, and the sale of books decreases, these trends are highly likely to continue. Digital reading is widely thought to have a much smaller greenhouse gas impact than reading from paper.

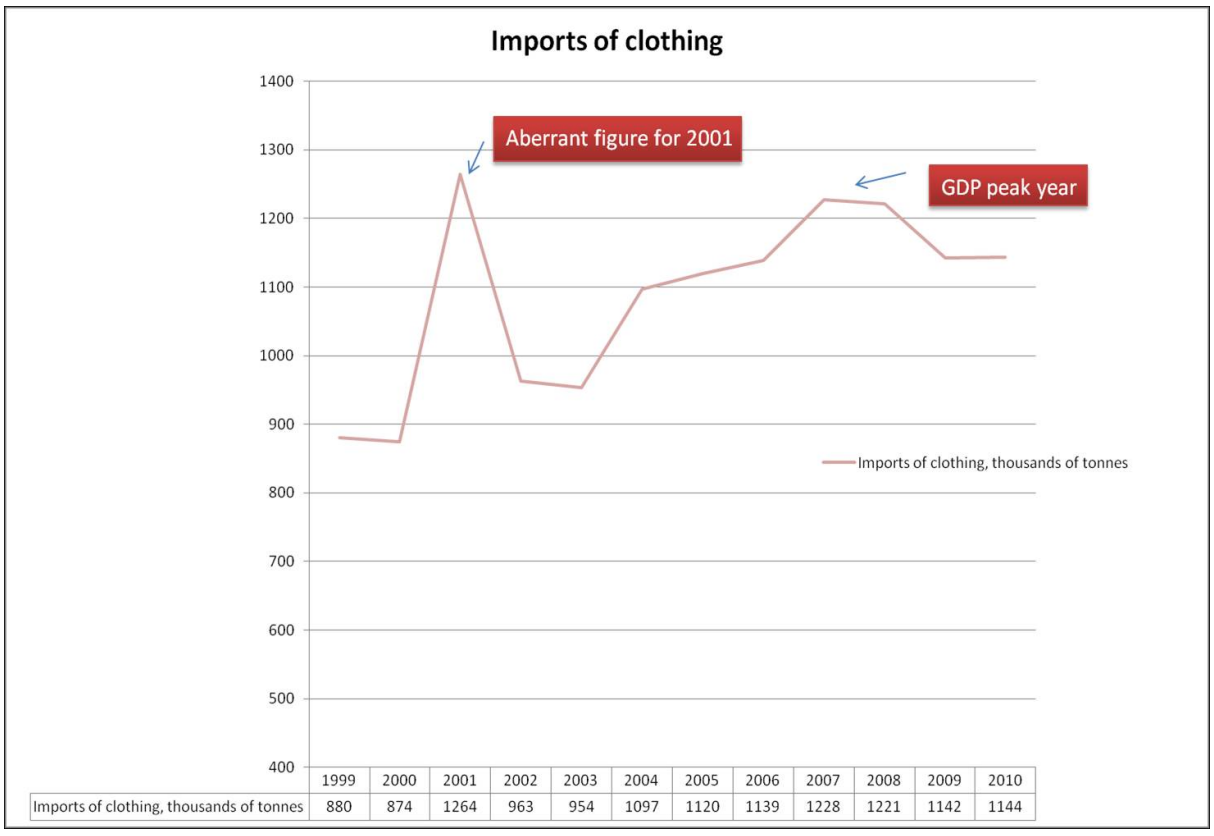
In addition, of course, the amount of virgin paper, as opposed to the recycled variety, that is produced is falling more sharply because of the increased focus on collection and reprocessing of used paper and cardboard. About 75% of all paper produced is now recovered for recycling. (But a piece of paper cannot be recycled more than five or six times before the fibres become too short. We will always need some new paper).

4) Textiles

Although clothing and other textiles used by consumers and businesses do not represent a large fraction of the total mass of goods in the economy, they are important because they have both a high carbon footprint and because the production of clothing has substantial ecological impact. About two million tonnes of clothing and other textiles are consumed every year in the UK, substantially less than one per cent of the total mass of goods passing through the economy and about a sixth of paper consumption. But many analyses of the impact of clothing manufacture show a picture of much more significance. For example, Patagonia, a large US outdoor clothing company, estimates that a single cotton shirt has a carbon footprint of 8 kg, about thirty times the weight of the product itself and needs over 2,300 litres of water during the cotton growing and garment manufacturing processes.[8]

Unlike all the other goods and services in this survey, the UK consumption of textiles does not show unambiguous evidence of a peak prior to the end of the boom. Data is not of good quality but almost all information suggests that the weight of clothing coming into the economy continued to grow until the peak year of 2007. The chart below shows the weight of clothing imports coming into the UK over the past ten years or so. Imports provide perhaps 90% of UK clothes so these figures are reasonable approximations to total British consumption.[9]

Chart 6



	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Imports of clothing, thousands of tonnes	880	874	1264	963	954	1097	1120	1139	1228	1221	1142	1144

Source: Overseas Trade Statistics of the United Kingdom. Clothing imports using the total weight under the SITC 84 heading

[8] This data can be found for a Pima cotton shirt at http://www.patagonia.com/us/footprint/index.jsp

[9] A study by Oakdene Hollins for Defra, *Maximising Reuse and Recycling of UK Clothing and Textiles,* suggests total purchasing of clothes by UK consumers of about 1.25m tonnes in 2007. Import data for the same year gives a figure of 1.23m tonnes. These figures are not directly comparable – retail sales will lag imports – but strongly suggest that imports are a very large percentage of total UK sales of clothes.

The chart has one aberration. The import figure for 2001 is much higher than the surrounding years. The UK trade data for that year records very unusually high imports from Italy: almost 500,000 tonnes, about 40% of the total imports and well over ten times the level of the following year. 2001 should therefore probably be ignored, meaning that 2007's imports are higher than any previous year. It was only the recession of 2008 onwards that dented growth.

How realistic is to use import statistics of clothing weight as an index of total UK consumption? This question is open to argument. Although the UK now produces relatively little clothing, national production was greater a decade ago. So using imports as the measure of trends in total clothing consumption slightly exaggerates the underlying growth. I have estimated the amount of total clothing production in the UK of goods that are consumed in the UK, rather than exported, and added these figures to the numbers for imports. The resulting figures, on which very little reliance should be placed, suggest that the weight of clothing bought by UK households and businesses rose about 16% between 2002 and 2007, compared to a 14% rise in real GDP.

In other words the picture for clothing is unlike any other goods in the rest of this paper. Volumes are rising faster than GDP and there is no decoupling whatsoever between consumption levels and GDP. This finding fits with the general view that 'fast fashion' – inexpensive clothes bought from chain stores – has produced a rise in the weight of clothing used by British consumers. This pattern is also shown by the apparent increase in the weight of clothing being discarded by British homes and businesses, either into municipal waste or being passed to recycling.[10]

5) Fertilisers

So far this investigation has looked at some of the key products made from what the Material Flow Accounts call 'biomass' – food, paper and clothing.[11] The products in this section – fertilisers, cement and cars – originate as minerals in the earth's crust or, in the case of nitrogenous fertilisers, as natural gas, a fossil fuel. The Haber Bosch process for making ammonia, the crucial step in making nitrogenous fertilisers, uses about 5% of all the natural gas produced globally. The run-off of reactive nitrogen from fields that have been fertilised is one of the primary causes of 'dead zones' in rivers and seas.

The application of nitrogen to UK fields peaked in 1987 and has been in almost continuous fall since then. Greater care in application has allowed farmers to maintain crop yields without using as much fertiliser. The amount applied in 2007 was 60% of the 1987 figure. Half of this reduction came in seven years from 2000.

Phosphate and potash fertilisation shows similar patterns. Phosphate application reached a peak in 1984 after decades of slow increase but has declined sharply since then. 2007 levels were less than 50% of 1984 figures and the long run decline appears to be continuing.

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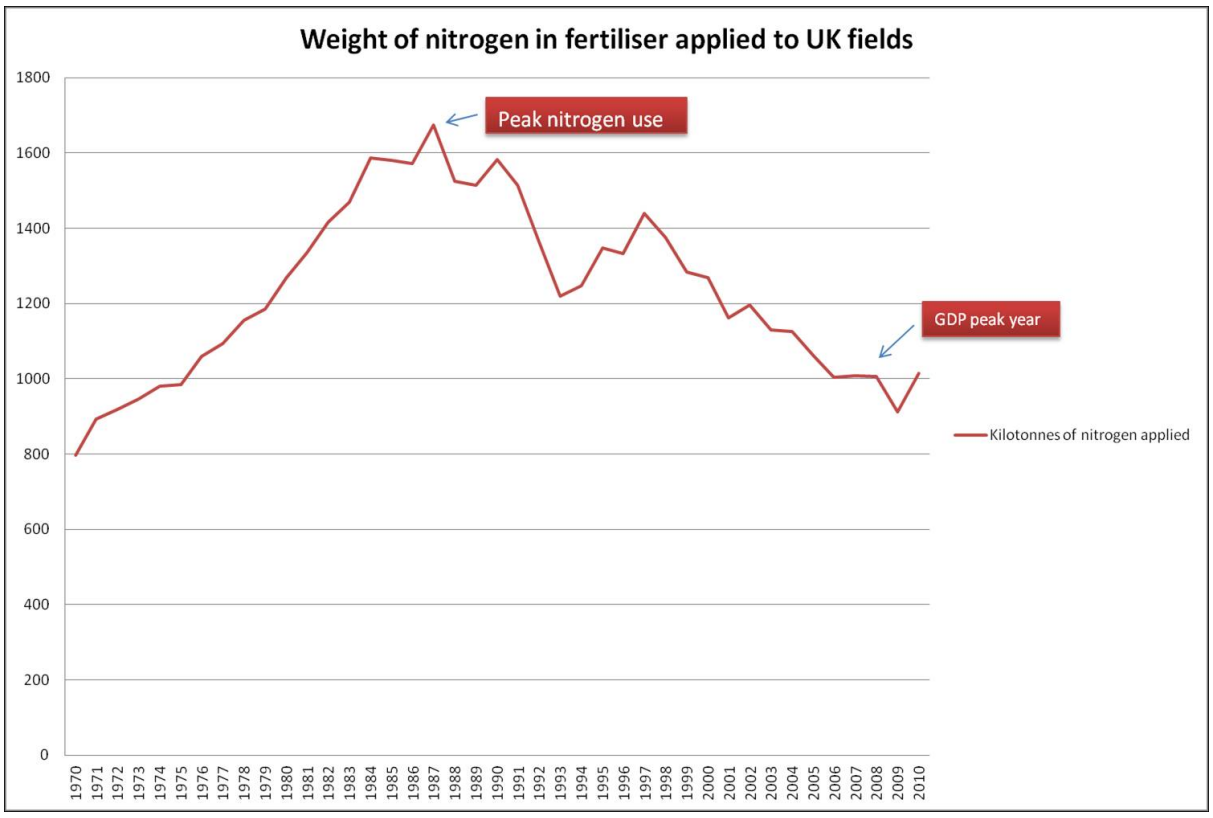
[10] Figures in the Oakdene Hollins study suggest that total weight of textiles (including clothing) discarded to municipal waste or reused or recycled rose from about 1.49m tonnes in 2003 to about 1.60m tonnes in 2008, a rise of about 7%.

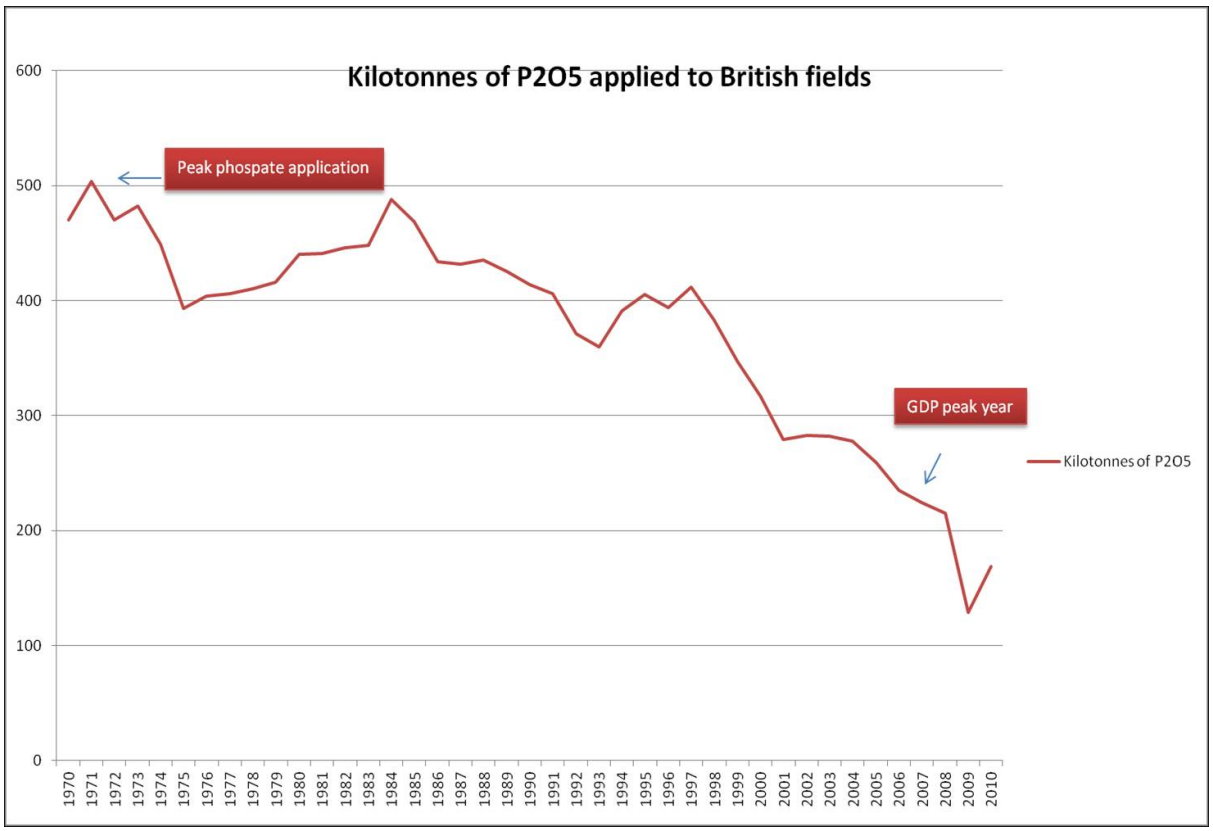
[11] Most clothing is now made from oil which has been processed into a plastic, but substantial amounts of textiles are still made from cotton, wool, silk, linen and other biologically derived materials such as viscose, ultimately coming from cellulose.

Chart 7



Source: British Survey of Fertiliser Practice 2011-09-09, table B.2.5

Chart 8



Source: British Survey of Fertiliser Practice 2011-09-09, table B.2.5

1984 was also a year of peak potassium use (in terms of kilotonnes of K2O). Usage had declined by about 43% by 2007 and the fall continues. The overall reduction in all types of artificial fertiliser application between 2000 and 2007 was about 25%.

One question immediately arises. Does the consistent reduction in tonnes of fertiliser applied to UK fields arise from a fall in the number of hectares actively cultivated? The area under cereals has, for example, tended to fall over the last fifteen years.[12] The British Survey of Fertiliser Practice provides estimates (in tables B2.1, B2.3 and B2.4) for applications rates per hectare for Great Britain. This data shows as follows.

Table 3

Summary of fertiliser application practices per hectare

Fertiliser	Nitrogen	Phosphate	Potassium
On tillage crops	A very slow decline. Application rates in 2007 were 148kg/ha, compared to an average of about 147kg/ha in the previous seven years. Application rates in the 1990s were very slightly lower and the 1980s higher	Application rates have fallen by over 40% since the peak years of the mid 1980s.	Application rates have fallen by about 25% since the peak years of the mid 1980s.
On grassland	Sharp and reasonably consistent declines in application rates since the mid 1980s	Use per hectare fell by half from 1983 to 2007. Reduction continuing	Rates fell by about half from the peak of 1990 to 2007. Sharp declines continue
Overall	Per hectare application rates peaked in 1991 at over 25% above the 2007 figure.	Typical reduction of about 40% between the mid 1980s and 2007.	Application per hectare down by about a third since the mid 1990s

Examination of application rates per hectare shows that rates for grasslands have fallen sharply for all fertilisers. Cropped land has a slightly more complicated picture, with nitrogen use only declining very slowly, if at all, but phosphate and potassium use falling markedly. There is no evidence therefore that fertiliser use is coupled with rises in the UK's GNP. This conclusion is not vitiated by a fall in the UK's self-sufficiency in crops that use large amounts of fertiliser: the country is still broadly self-sufficient in cereals, for example, which are the crops receiving most fertiliser.

6) Cement

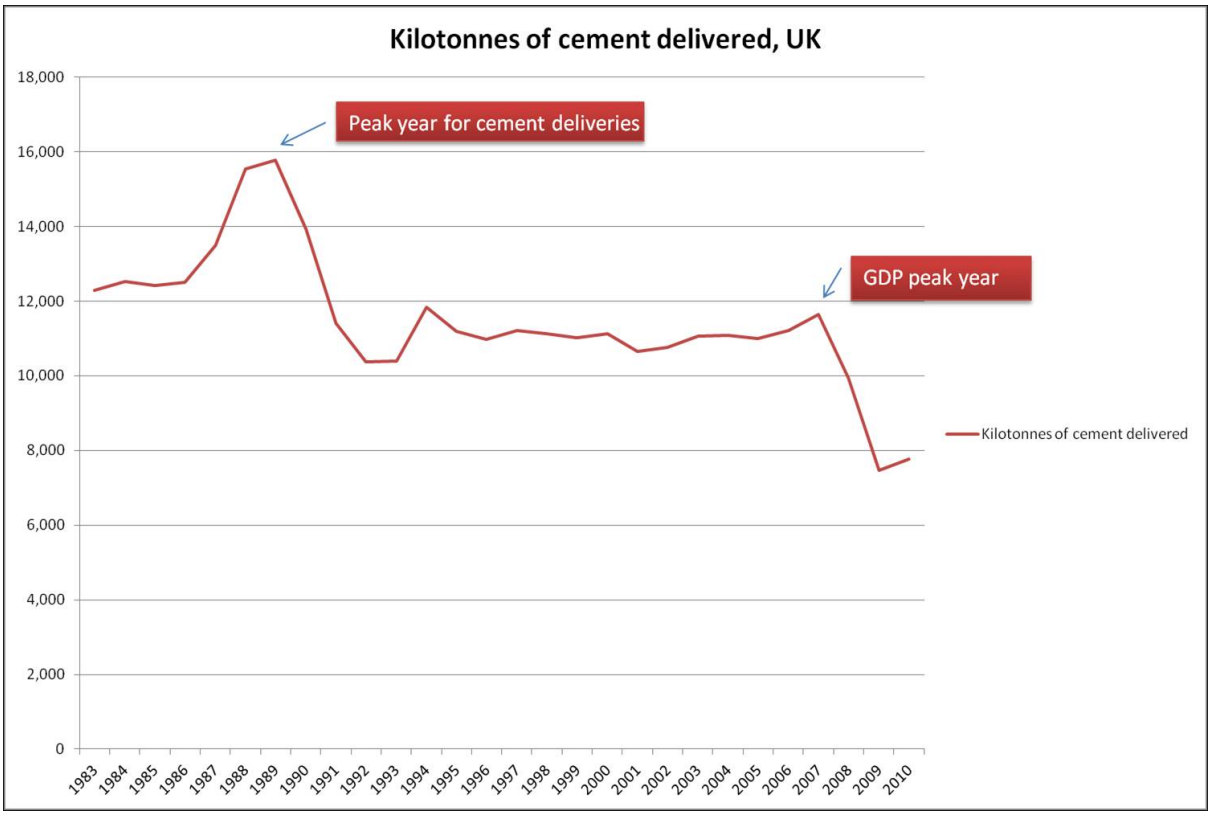
The making of cement uses large amounts of energy. In addition, the process produces large amounts of CO2, driven off the calcium carbonate that is the main raw material for this vital building material. The worldwide cement industry is responsible for about 5% of global greenhouse gas emissions. The mining of calcium carbonate and the other raw materials used in the cement kiln also imposes environmental

[12] The area used for cereals was about 3.36 million hectares in 1996 and about 3.01 million hectares in 2010, a reduction of about 10%.

damages. Cement and other construction materials are responsible for a large fraction of the 300m tonnes of minerals that were extracted in the UK in 2007.

The collapse in UK construction since 2007 has reduced cement use by over a third. But 2007's production volumes were broadly similar to the typical year of the previous fifteen years. The peak year for deliveries of cement in the UK was 1989 when volumes were about 30% higher than during the boom years of the last decade.

Chart 9



Source: Department of Business, Innovation and Skills, *Construction Building Materials,* Table 8, supplemented by data from BIS statisticians in a personal communication.

2007 cement deliveries were the highest for over ten years at 11.6 million tonnes. The average for the preceding ten years was six per cent lower. However this year was unusually high and previous years had been broadly flat at around 11 to 11.2 million tonnes. The 1980's had seen much higher levels of cement deliveries every year, with 1989 seeing a figure over a third higher than in 2007. Other major construction materials, such as blocks and bricks, saw no 2007 peak. Concrete deliveries were slightly up on the average of the previous few years but were still well down on the 1989 peak. Sand and gravel extraction peaked in 1989 with a more recent lower peak in 2002. Between 2002 and 2007 extraction fell by about 15%. This index has continued to fall sharply since the 2007 economic peak and is now at about half the tonnage of the early 1980s.

These consistent figures from the construction sector are entirely compatible with the UK's Material Flow Accounts, which show a fall of about one third in mineral extraction from 1989 to 2007. Most of the fall in mineral mining occurred during the 1990s but even after a decade of sustained economic

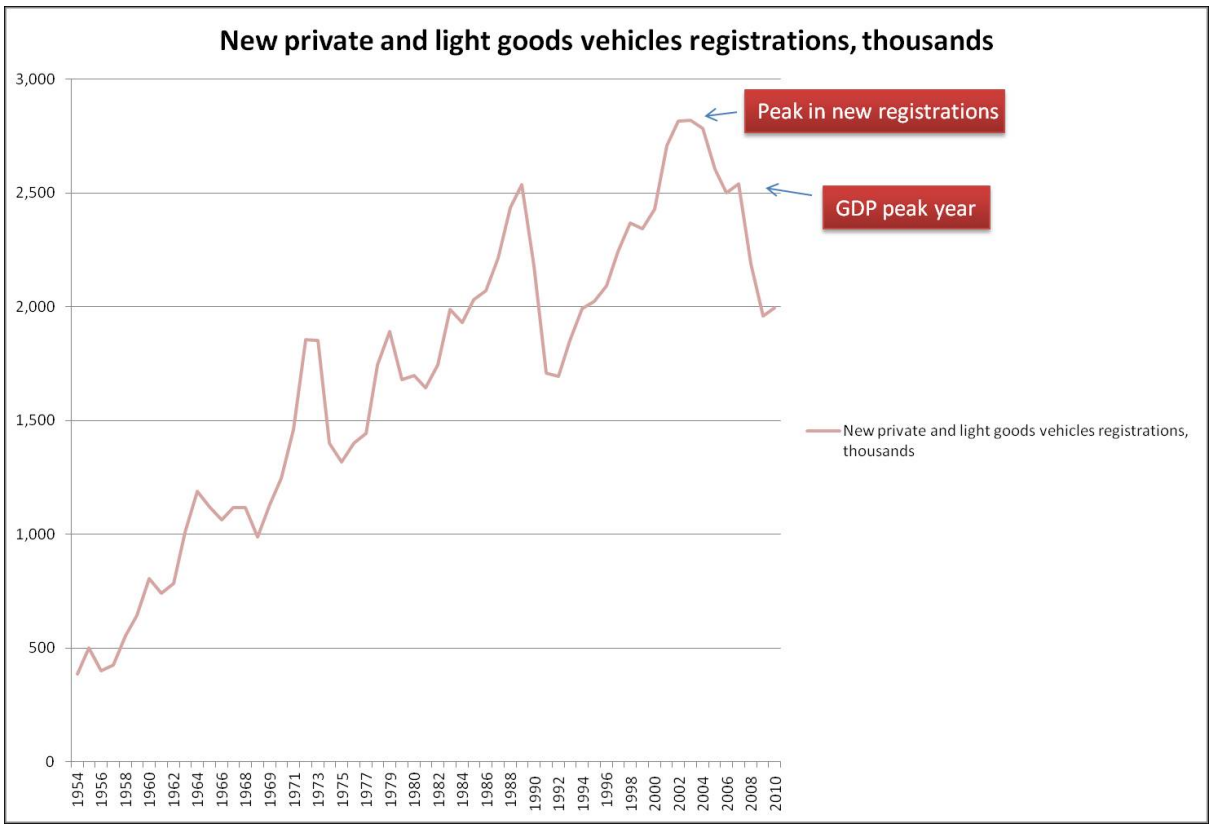
growth the Material Flow Accounts show that 2007's extraction was below the average of the preceding ten years. Heavy building materials use appears to be decoupled from economic growth.

7) Cars

In his book on carbon footprinting, Mike Berners-Lee estimates that a newly-built Ford Mondeo car has a total carbon footprint equivalent to about 17 tonnes of CO2.[13] Since the average yearly carbon footprint per person will have to decline to a few tonnes a year, continued growth in the number of new cars produced is incompatible with the UK meeting its climate change targets.

The number of cars newly registered on UK roads peaked in 2003. The 2007 figure was 10% lower.[14] (Sales also swung towards smaller models, tending to reduce the carbon footprint of the vehicle, although there has been some compensating increase in the weight of cars, taking the weight of the average UK in 2007 to a level almost as high as the peak in 2003). The pattern is similar with other types of motor vehicles. Goods vehicle registrations peaked in the late 1980s and fell erratically to 2007, with registrations in this year a full 20% below the levels of just two years before. The recent peak in motorcycle registrations was in the year 2000 with the 2007 figure over a fifth lower. Bus volumes were up but still below the peak of 1988.

Chart 10



Source: Department of Transport, Vehicle Licensing Statistics, Table VEH0153

[13] Mike Berners-Lee, *How Bad Are Bananas,* Profile Books, 2010, page 143.

[14] European Environment Agency data suggests similar patterns in some EU countries and not in others. See page 12 of Monitoring CO2 emissions of new Passenger cars in EU27, a publication of the EEA, page 12.

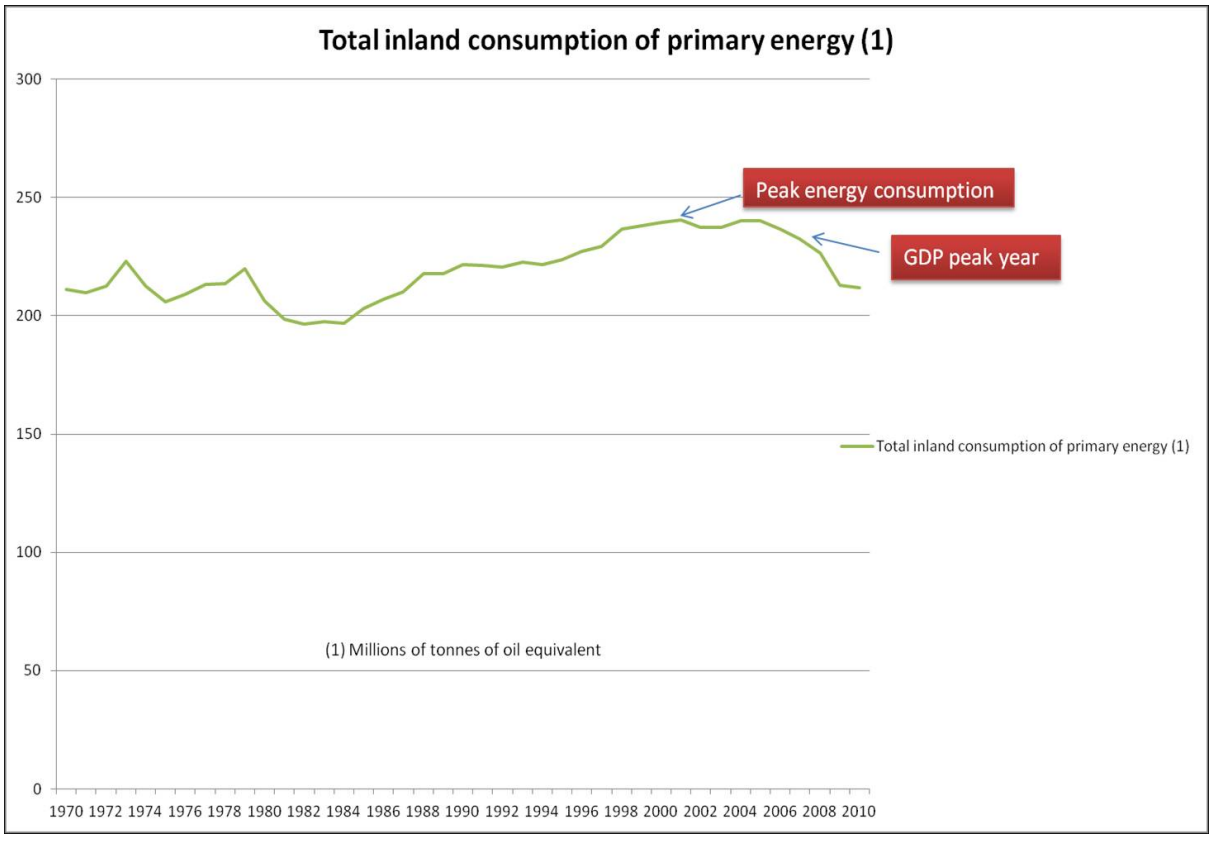
The total number of cars – not just new registrations – on British roads is still tending very slightly upwards, although this position has probably reversed in the last few months. But the total numbers of buses, goods vehicles and motorcycles on the roads have all started to fall. In the case of goods vehicles, the decline supports the idea that the total volumes of materials being shipped around the economy may be falling.

8) Energy use

In the last section, I looked at some of the goods that use the largest amount of minerals extracted from the earth's crust. In this portion of the paper, I look at two indications of trends in fossil fuel use, the third element of the Material Flow Accounts.

The amount of primary energy produced in the UK peaked in 2001.[15] The 2007 figure was over 3% lower. This figure includes all consumption of fuels, including such things as motor fuels for cars, coal for power stations and natural gas in businesses and homes.

Chart 11



(1) Millions of tonnes of oil equivalent, temperature corrected
Source: Digest of UK Energy Statistics (DUKES) Table 1.1.4.

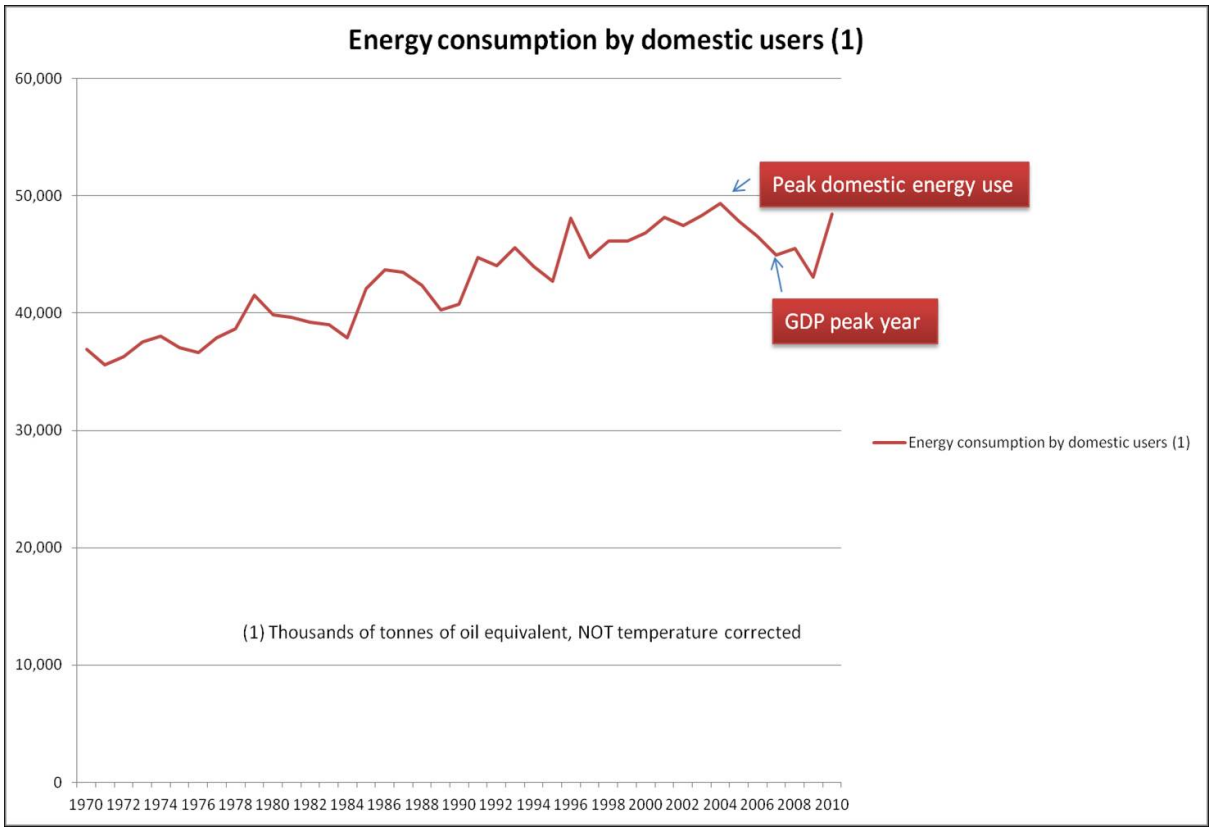
[15] Primary energy use is the sum of all the fossil fuels burnt, nuclear power generated plus renewable energy. It is different from energy consumption, largely because some fossil fuels are used (at varying levels of efficiency, with considerable loss of heat to the atmosphere) to generate electricity. Primary energy use includes all the fuels burnt in power stations. Energy consumption measures the smaller amount of electricity that is supplied to customers.

Energy consumption by final users reached its maximum in 2004, with the 2007 figure about 3.5% lower. Both measures have seen further sharp falls. Primary energy consumption, including that lost in the conversion to electricity, is now at about the same level as in 1970 even though real GDP is now well over twice the size . Consumption by final users of fuels and electricity is also down to levels of forty years ago.

One criticism of this approach is to point to the deindustrialisation of the UK over the past forty years. Heavy industry is a major consumer of energy and its gradual decline will have helped stabilise UK energy use. So need to look at patterns of use in other sectors. Final energy consumption by domestic users reached a peak in 2004 and fell by 9% to 2007. It continued to fall in the two following years but the winter of 2010 – the coldest for over two decades – saw sharply increased gas demand from private homes, reversing some of the reduction since 2004. (Unlike primary energy data, these numbers are not temperature corrected.) 2011 saw a resumption of falling domestic energy demand. Final energy consumption fell by 6½ per cent between the first quarter of 2010 and the first quarter of 2011, with falls in all sectors mainly due to the milder weather conditions.[16]

Electricity demand in homes, which is not as affected by temperatures as gas and heating oil demand, was 6% lower in 2010 than its peak in 2005.

Chart 12



Source: Digest of UK Energy Statistics ('DUKES'), Table 1.1.5

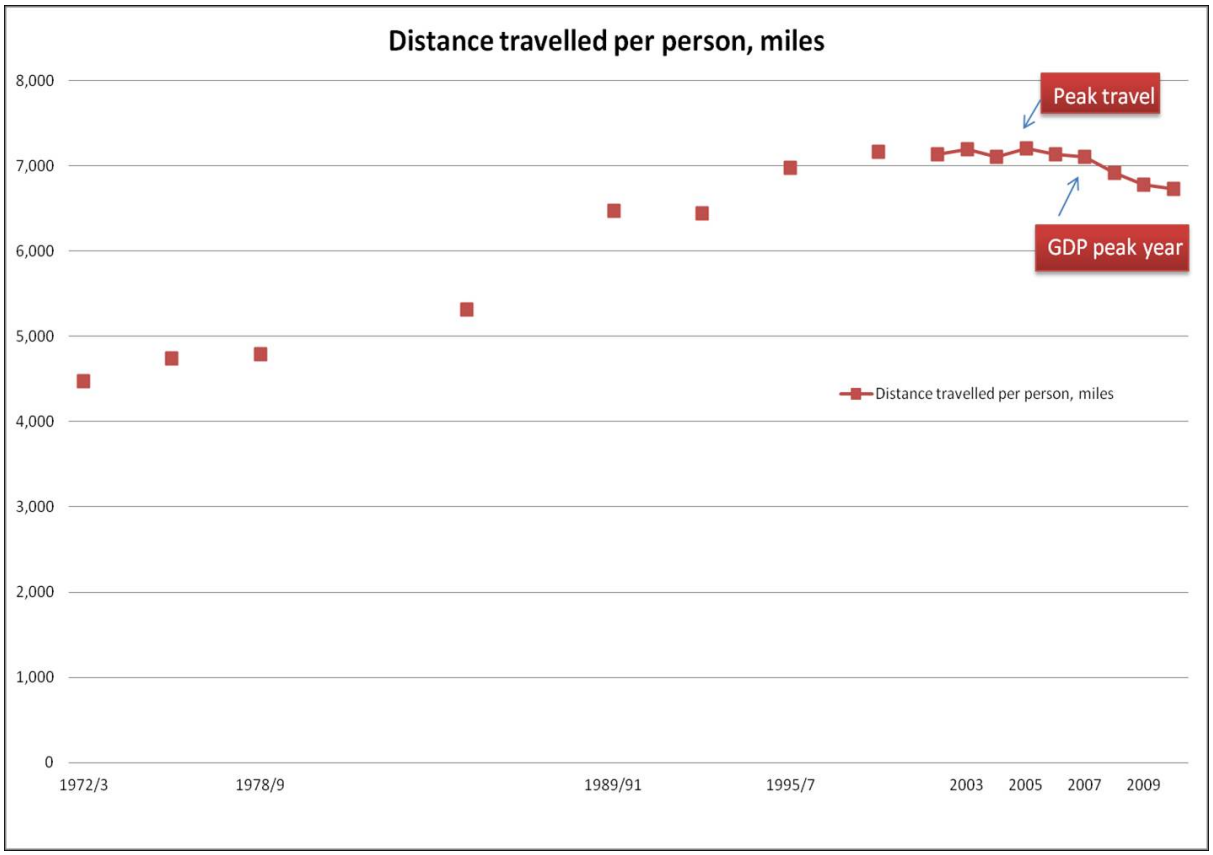
[16] Source: Energy Trends, DECC, June 2011

9) Travel

Section 8 on Energy looked at the total use of primary energy across the economy and, second, final consumption specifically focusing on domestic use. Another important, but separate, indicator of energy use is the amount of oil refined for transport fuels. This reached a peak in 2007, having risen just four per cent over the previous ten years.

However the amount of travel (in kilometres) has fallen sharply for individuals since its peak in 2005. In that year the National Travel Survey showed that the average person travelled 7,208 miles. This number fell by about 1.5% by 2007 to 7,103 miles and has since decreased sharply. (These figures exclude air travel. Flying has increased substantially, but the volume of aviation fuel burnt has fallen in the four recorded years since 2006)

Chart 13



Source: Department for Transport, National Travel Survey, 2011

The typical distance a person travelled as a car driver peaked in 1998 and by 2007 was no higher than the 1995/97 figure. Distance as a car passenger peaked in 2002 and has decreased by 14% since that date. By contrast, miles on a bicycle – an activity much less demanding of natural resources than using a car – shrank until about 2002 but have risen most years since then.

The overall number of trips of more than one mile taken using all modes of transport reached its maximum in 2002 and fell by over 4% by 2007. The time spent travelling peaked in 2005. Researchers have noted similar results in other developed countries.[17]

10) Waste

When physical goods are disposed of, they become waste. Over the very long term, the reductions in inputs seen in the Material Flow Accounts must, as a matter of logic, translate into reduced amounts of waste.

Waste can be in solid, liquid or gaseous form. Gases, such as CO2 from combustion or methane from anaerobic decay, are added to the atmosphere. Liquid waste tends to flow into watercourses. Solid waste is either put into landfill or added to the soil.

Running through these wastes in turn, we know that the volume of greenhouse gases emitted by the UK has fallen in most years since 1990. But this may not be a reflection of underlying falls in energy requirements. Increasing amounts of embedded energy are coming into the UK in the form of manufactured goods. Several studies have suggested that the UK's national carbon footprint has actually increased as a result of the substitution of imported goods for domestic equivalents.[18] (But, please note, the present paper is not principally concerned with greenhouse gas emissions but rather with resource use).

Only 5% of all waste is in the form of liquid that is added to bodies of water so is not an important determinant of whether weights of waste are rising or falling. In the case of solid waste, we have good evidence that waste arising peaked in the early or mid part of the last decade and clearly before the economic peak of 2007.

The most visible waste is that produced by households and small business and collected by local authorities. But it is only about 10% of all waste arising in the UK. The amount of waste collected by local authorities, including that recycled, reused or composted, reached a maximum in 2003/4 at about 29 million tonnes and this number had fallen by about 2% by 2007/8. (It has fallen by over 7% since then).

The amount of household waste collected per person fell by 5% between 2002/3 (the peak of per person domestic waste) and 2007/8. This number has also declined sharply since. As importantly, a rapidly rising percentage of this figure is being recycled – as in the case of plastics, paper clothes and metals – or being composted, in the case of food waste. A decade ago, only about 10% of household waste was recirculated rather than being dumped. Now the figure is almost four times as great.

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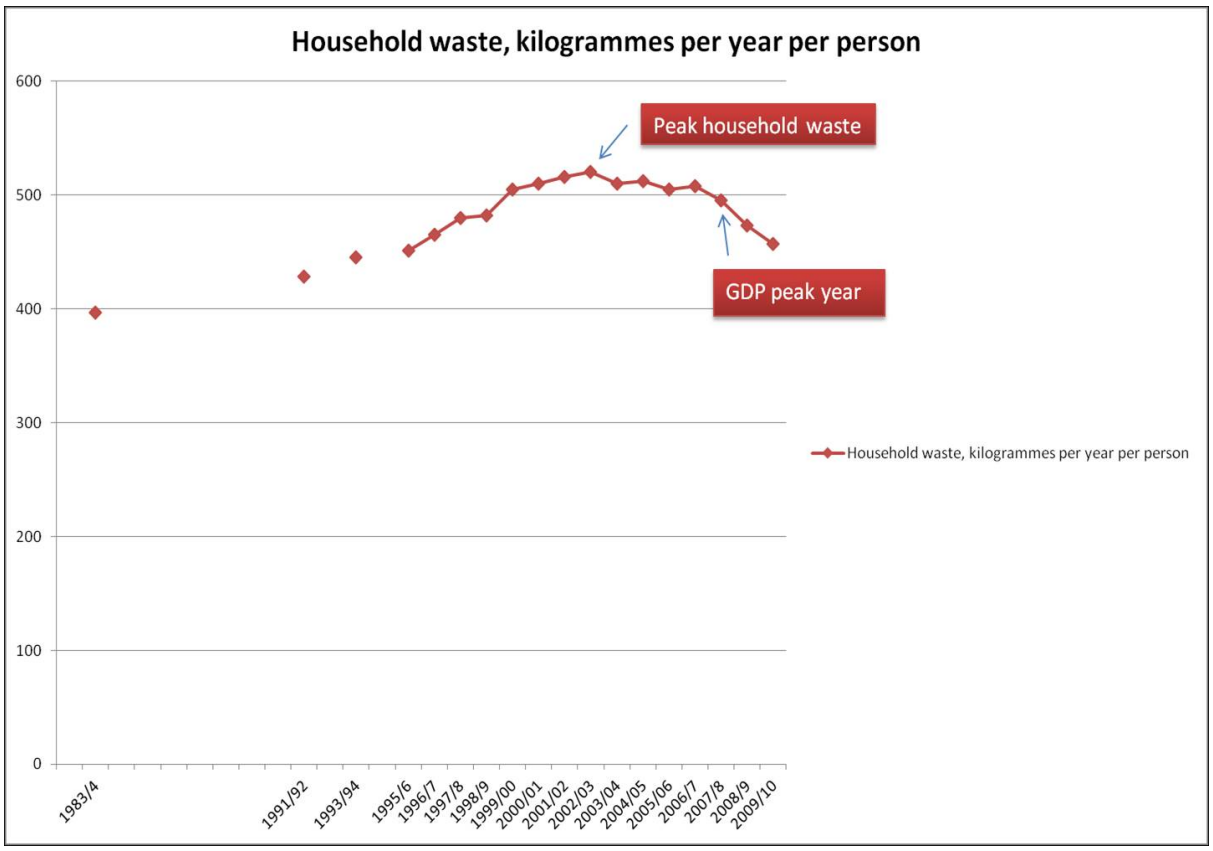
[17] A Millard-Ball and L Schipper, *Are We Reaching 'Peak Travel'? Trends In Passenger Transport In Eight Industrialized Countries,* submitted to Transport Reviews, 2011

[18] E.g. Helm, D., Smale, R., Phillips, J. (2007) *Too Good to be True? The UK's Climate Change Record*

Chart 14



Source: Defra, household waste per person and per household.

Although all the attention falls on household waste, disposals from demolition and from mineral extraction are far more important in weight terms. Defra data suggests that construction and demolition waste fell from 113.2 million tonnes in 2004 to 109.5 million tonnes in 2006 and 101.0 million tonnes in 2008.[19]

Commercial and industrial waste declined from 67.9 million tonnes in 2002/3 to 47.9 million tonnes in 2009, a fall of 29%. (Information on the relationship between the peak year and the volumes for 2007 is not immediately available).

Conclusion

We have looked at the weight of material flowing into the British economy, the volume of goods and usable energy this material generates, and the amount then requiring waste disposal in some way. A sustainable world economy requires the amount of new biomass, minerals and fossil fuel to stabilise and fall in absolute terms. This paper has demonstrated a possibility that the totals in each stage of the process began to fall in the early to mid part of the last decade.

The UK is a small part of the world economy, with about 2% of its GDP, though patterns seen here may possibly be similar to some other high income countries. The material arriving into the economy peaked

[19] Defra, Waste Data Overview, June 2011

in about 2001. Water use, the other major input reached a maximum in 2003/4. Food use per person has been falling for decades but, crucially, meat consumption peaked in 2003. Meat is particularly important because animals need large amounts of food inputs to create one unit of meat. Paper production also requires biomass and use has been falling since 2001.

Goods made for us, such as cars, cement and fertilisers all see peaks well before the top of the last boom and appear to be in decline in absolute terms. Clothing may be the exception: the evidence is that it was still growing with the economy until 2007. These products were chosen because they are amongst the most energy and resource intensive of all goods.

Primary energy use has been falling since the 2001 or so. Travel, excluding air flights, has been in decline since 2005. At the conclusion of the cycle of resource use, waste volumes have been falling since the early part of the last decade.

One obvious question about all these figures is whether they simply reflect the de-industrialisation of the UK, a process that will tend to cut resource use. UK Material Flow Accounts may not, for example, be adequately capturing the fossil fuels used to make goods in China then shipped to the UK. Where possible, I have therefore introduced a separate measure of household, as opposed to industrial or institutional usage to provide a check that falling industrial activity is not causing the phenomena noted in this paper. However, it should be noted that many of the indices I track, such cement use, paper consumption or fertiliser application, are measuring the actual consumption of a good in the UK. Whether the material is imported or not is irrelevant. Even if much more cement was imported in the boom of 2007 than in 2000 (it was not) it doesn't change the picture of an economy that seems to be simply using less construction materials than it used to.

I do not devote much attention in this paper to commenting on *why* the peak of physical resource use may have been reached. Readers of the draft version produced their own hypotheses noting, for example, that the peak in the number of households moving house that occurred in 2002 may be correlated with the amount of purchasing of new items such as furniture. Another potential explanation is that the economic growth in the period to 2007 was not universally shared among the UK population. A large fraction of the total increase in GDP was captured by the very highest income earners. Although the national figures suggested improving prosperity, the disposable income of all but the top 1% may have been largely static.

Whatever the reason, the clear pattern of absolute decline across the UK economy shows that absolute decoupling of resource use from economic growth may possibly have occurred. Much faster declines will well be required in rich countries if the world is to share the earth's resources equitably as the rising economies continue to industrialise. But it is a hypothesis that suggests that economic growth is not *necessarily* incompatible with sustainability. In fact GDP growth, because it brings technological progress which is correlated with more efficient use of resources, may help reduce environmental damage.

Table 4

Summary of data in this paper

Category		Peak year	Decline between peak and 2007
Inputs	Total Material Requirement	2001	4%
	Direct Material Consumption	2001	5%
	Water (overall)	2003/4	4%
	Water (household)	2003/4	4%
Uses of biomass	Food (calories per head)	About the 1960s	Tens of percent
	Food (grammes of meat per person)	2003	3%
	Paper	2001	6%
	Textiles*	2007	May not have peaked
Uses of minerals	Cement	1984	26%
	Cars	2003	10%
	Some fertilisers (P and K)	Mid 1980s	More than 50%
Use of fossil fuels	Primary energy production	2001	3%
	Travel	2005	1%
	Some fertilisers (N)	1987	40%
Waste	Overall waste	Early part of last decade	Tens of percent
	Domestic waste per household	2002/3	5%

*Textiles are either made from biomass or from fossil fuels