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Invisible Energy Policy – Analysis of the link between consumption and energy demand

John Barrett[1], Kate Scott, Anne Owen, Jannik Giesekam

(Sustainability Research Institute, School of Earth and Environment, University of Leeds)

Keywords

Energy demand, industrial energy, energy intensity, consumption

Abstract

Energy demand is driven by the consumption of goods and services by households and government. The UK has now seen a moderate annual reduction in energy demand for over 10 years. This paper explores whether this is predominately due to the outsourcing of energy demand to other countries to satisfy UK consumption, or whether energy efficiency policies in the UK are responsible for the reduction. The analysis considers progress in four high level sectors, these being industry, transport, services and domestic (i.e. housing). Finally, the paper evaluates the potential role of domestic “efficiency” and “demand” policies in capturing the UK’s energy consumption, accounting for trade.

Consumption based accounting techniques provide a valuable link between the consumption of final goods and services and the energy required to produce them throughout the whole supply chain. With the use of a Multi-Regional Input Output Model, this paper identifies the role of non-energy policy in driving energy demand. We explore the link between infrastructure, transport and product policy with energy use for the UK. We propose that to address energy demand reduction, a complete economy-wide approach is required with a focus on consumption.

1. Introduction

Reducing energy is an essential criterion for achieving sustainable lifestyles and delivering numerous societal objectives[2]. Climate and energy policy prioritises the deployment of low carbon energy and the development of unproven-at-scale negative emissions technologies (e.g. carbon capture and storage). The need for greater demand reduction has been reflected in recent evidence from the International Energy Agency (IEA) and Intergovernmental Panel on Climate Change (IPCC), and the EU have put targets in place to reduce energy demand[3], yet this receives disproportionately little support from current policy and regulation. There is considerable evidence to support the claim that energy demand reduction provides an immediate and effective low risk response to climate mitigation[4] alongside improving energy security, reducing fuel poverty and raising economic activity[3].

Energy demand is often explained by patterns of economic growth. The conventional economic growth approach to understanding the energy-economy relationship is measured as the proportion of GDP spent on direct energy compared to capital and labour costs [5] [6]. Studies consistently show a relative decoupling of energy consumption from economic growth since the 1970s, explained by global processes of industrialisation and economic restructuring [3]. As countries industrialise they shift to less energy-intensive industries, reduce their direct demand for energy and restructure to produce higher value service-based products[5]. In comparison to the high costs of capital and labour, energy is deemed of little importance in driving economic growth and is often depicted as being substitutable with capital [7].

However, Ayres and Warr (2005) demonstrate how the role of energy is greater than the payment made for it, describing it as the 'engine for growth'[5]. The standard measure captures primary energy as a direct input to the production process, but not the efficiency in which primary energy is converted, or the dependence of other production processes for the physical output in the form of goods and services, coined as 'useful work'. In other words, production outputs require not only direct energy inputs, but indirect inputs (goods and services) within which energy is embodied [8]. Therefore energy consumption is not an 'end product' in itself but delivers, directly and indirectly, all the goods and services purchased by households and government to satisfy humanity's needs. An understanding of future household requirements in terms of goods and services is needed to understand present and future energy demand. This requires an understanding of how consumption is structured and evolves and the complex bi-lateral relationship between energy production and end-user consumption.

Progress on reducing energy demand requires asking the fundamental question as to whether it is possible to break the link between economic growth and increasing energy demand. This paper maps the energy demand of all UK household consumption. It explores the level of decoupling between economic growth and energy demand and considers the wider implications of non-energy policy on energy demand. The response to reducing energy demand has historically been to introduce sectoral level energy efficiency strategies. This paper proposes that while this approach can provide relative decoupling between economic growth and energy demand, it cannot deliver the absolute decoupling that is required to make a substantial contribution to the global mitigation requirements to avoid catastrophic climate change. This requires a more fundamental approach where all areas of government implement an "energy demand management strategy" to ensure that demand for energy reduces as well as promoting more efficient use. We call this "Invisible Energy Policy".

The paper is structured as follows:

- A review of the UK policy context
- Methodology
- Results for the UK
- Analysis of Invisible Energy Policy in the UK
- Discussion and suggestions for further research

2. Policy context

Within the UK, the responsibility to deliver energy efficiency across all sectors of the economy rests within the Department for Business, Energy and Industrial Strategy (BEIS). Traditionally, energy consumption has been sub-divided into the high level sector classifications of industry, transport, domestic and services. Demand reduction is largely implemented hand in hand with energy efficiency, and only modest suggested reductions in energy consumption. Progress has been made across all sectors. For example, insulation and efficient gas boilers have improved the energy efficiency in buildings, in transport conventional vehicles have reduced to 125 gCO_2/km in 2014 from 170 gCO_2/km in 2000, and industry has improved energy management and process control, the use of more energy efficient plants and equipment and waste heat recovery[2]. Beyond some behavioural change mechanisms, there are not further policies to ensure a decrease in energy demand.

This does not recognise (1) that it is cheaper to mitigate now to avoid more rapid and costly reductions in the future, (2) the uncertain nature of deployment of low and negative carbon technologies [9], and (3) that improvements in energy efficiency does not necessarily reduce energy demand due to rebound effects[10]. To meet future carbon budgets requires a step change to unprecedented rates of emissions reductions[4], which makes the prioritisation of low carbon energy deployment and the development of unproven-at-scale negative emissions technologies (e.g. BECCS) a risky strategy. If less is achieved through reducing demand for energy; energy supply will have to decarbonise further and faster, significantly increasing the cost of abatement. Demand reduction is therefore an important transition mechanism while effective supply-side technologies are developed and necessitates an appropriate policy response.

Sorrell (2015) suggests however that *"[t]he link between energy efficiency and reduced energy demand is not straightforward: the first need not necessarily lead to the second"*[2]. Energy efficiency is a measure of *"useful outputs to energy inputs"* [11]. For example, we could measure the energy efficiency of transport as the energy input per vehicle km, or for industry, economic output per energy input. This measure does not take into account the wider societal effects that could influence whether the efficiency gains lead to a reduction in energy demand. For example, passenger kms could be increasing due to households travelling longer distances and at lower occupancy rates.

The effects of energy efficiency on demand reduction can be diminished by what are termed rebound effects. These refer to the economic response to an energy efficiency measure. Rebound effects can be direct; for example if a car is more fuel efficient the owner may choose to drive further, offsetting any energy savings. They can also be indirect; for example the savings from fuel costs of a more efficient car could be spent on other goods, which require energy to produce. And finally, a reduction in fuel demand could reduce fuel prices and increase fuel consumption in other parts of the economy. While micro-rebound effects are sometimes considered in energy policy, such as households turning up their heating and offsetting the savings from the instalment of insulation, the larger more difficult to calculate macro-rebound effects are not considered. As Sorrell (2015) points out, these are extremely difficult to calculate but the best available evidence suggests that they are higher than previously thought and can offset or eliminate savings from energy efficiency by more than 50% [3][12].

As well as wider societal rebound effects there are also issues associated with the production-based method of accounting for energy consumption. All UK Government publications related to energy refer to energy demand within the UK as opposed to the energy demand required to satisfy UK consumption[13]. This fails to take into account embodied energy, which can originate abroad. The UK has one of the largest 'GHG emissions trade imbalances', meaning that emissions embodied in imports are considerably higher than those embodied in its exports. As a result of globalisation, high income countries are able to partially externalise their environmental impacts through trade. An increase in the volume and structure of international trade has enabled production activities, and their emissions, to be transferred outside the country of consumption, referred to as carbon leakage [14] [15]. Kanemoto et al. (2014) show that emissions transfers are undermining international carbon targets[16].

This paper will provide the first comprehensive assessment of the energy embodied in UK consumption. This provides a more comprehensive picture that either supports or rejects the notion that decoupling between economic growth and energy consumption is a result of trade imbalances.

3. Methods

Humanity's demand for energy is a direct consequence of the consumption of households. Every good or service delivered to households has an associated supply chain where energy was required at each stage. Traditional analysis that attempts to outline how energy demand can be reduced often focuses on a sector approach, exploring the energy efficiency opportunities in different industry sectors, transport, housing and other buildings etc. While these approaches can identify many energy efficiency opportunities, they fail to recognise the underlying driver of energy demand – household consumption.

The methodology employed in this paper is a "Multi-Regional Input Output" model (MRIO) to link energy demand to household consumption in the UK. We derive the "Consumption based Energy Accounts" (CBA - Energy) for the UK, taking into account the full complexity of global supply chains to deliver final goods and services to households and government.

MRIO is a well-established method to re-allocate environmental pressures, such as energy, associated with production activities to the final demand of products [17]. It has been widely used in the area of economic, ecological and environmental modelling [18][19][20]. It has been used for decades to calculate consumption based environmental pressures of nations, sub-national entities, socio-economic groups and organisations or companies [21][22][23].

The strength of this approach is that it addresses production and consumption processes and their underlying technical, social and behavioural drivers simultaneously. The indicators derived illustrate the environmental impacts associated with consumption activities but the methodology used makes it possible to track product groups along the global supply chain. The methodology also allows for the impacts of imports to the country of interest to be considered separately from the impacts of domestically produced goods. This is done by creating a multi-regional model that distinguishes production technologies in the country of interest and other trading partners.

The MRIO database used in this study is based on the Eora MRIO database. Eora version 199.83 is a one of the most detailed MRIO databases available, comprising data from almost 200 countries and covering the time period 1970-2013. We use a version of Eora aggregated to four regions (the UK, Europe, China and the rest of the world (ROW) and the sectors mapped to the 106 sector classification employed by the UK's Office of National Statistics (ONS).

Whereas Eora provides the economic transactions data for the MRIO model, the industrial energy data is provided by the International Energy Agency (IEA). We use the IEA energy balance data to describe the energy used by each of the 106 sectors in each of the four regions. To do this we take total final consumption energy data, measured in terajoules and assign this to the relevant industry sectors. Whereas the ONS sectors are at a greater level of detail than the sectors used by the IEA, economic output is used to disaggregate the energy data. In addition, energy used by the energy sector and the energy lost through transformation processes are assigned to the relevant energy provider sectors and international aviation and marine bunker data is assigned to the air and marine transportation sectors, respectively. This generates an 'energy-used extension vector' that can be used alongside the economic data to calculate the consumption-based energy account for the UK.

4. Results

Figure 1 provides an analysis of the consumption-based energy accounts compared to territorial energy use. As a reminder, the territorial energy use represents the standard approach adopted by the UK Government.

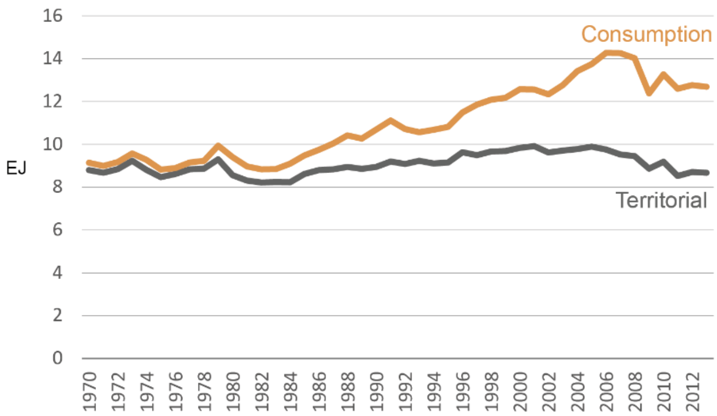

Figure 1 – UK Energy Demand from a Consumption and Production Perspective
Sources: Consumption based accounts – our calculations, Territorial based accounts [24]

The energy demand within the UK is almost identical in 2013 as it was in 1970, meaning that there has been no reduction for the past 44 years. If the UK produced all the goods and services inside the UK to satisfy UK consumption as opposed to relying on imports, the energy demand would have increased substantially between 1970 and 2013 (by 46%). Figure 1 demonstrates that between 1970 to 2013, there has been an increase in energy demand in the UK when taking account of the energy demand from a consumption perspective. However, since 2008 there has been a reduction in both the energy demand from a territorial and consumption perspective. The primary reason for this surpressed demadn relates to the reduction in expenditure due to the global fincancial crisis.

The argument often made by the UK Government is that the energy demand would have increased considerably if energy efficiency policies had not been introduced. An example of this is an analysis that calculated the historical counterfactual if insulation and more efficient boilers had not been installed in UK households. The analysis suggests that household energy use would have been twice as high if efficiency standards were not introduced[25]. Therefore, it is not as simple as suggesting that energy related policies have failed, but it is possible to conclude that policies have not been implemented at a level that has resulted in a reduction in UK energy demand from 1970 to 2013.

Figure 2a and 2b provides further insights into the UK energy demand by provided a highly aggregated disaggregation into four sectors. These have been selected to allow for consistent comparison between the territorial and consumption based energy analysis.

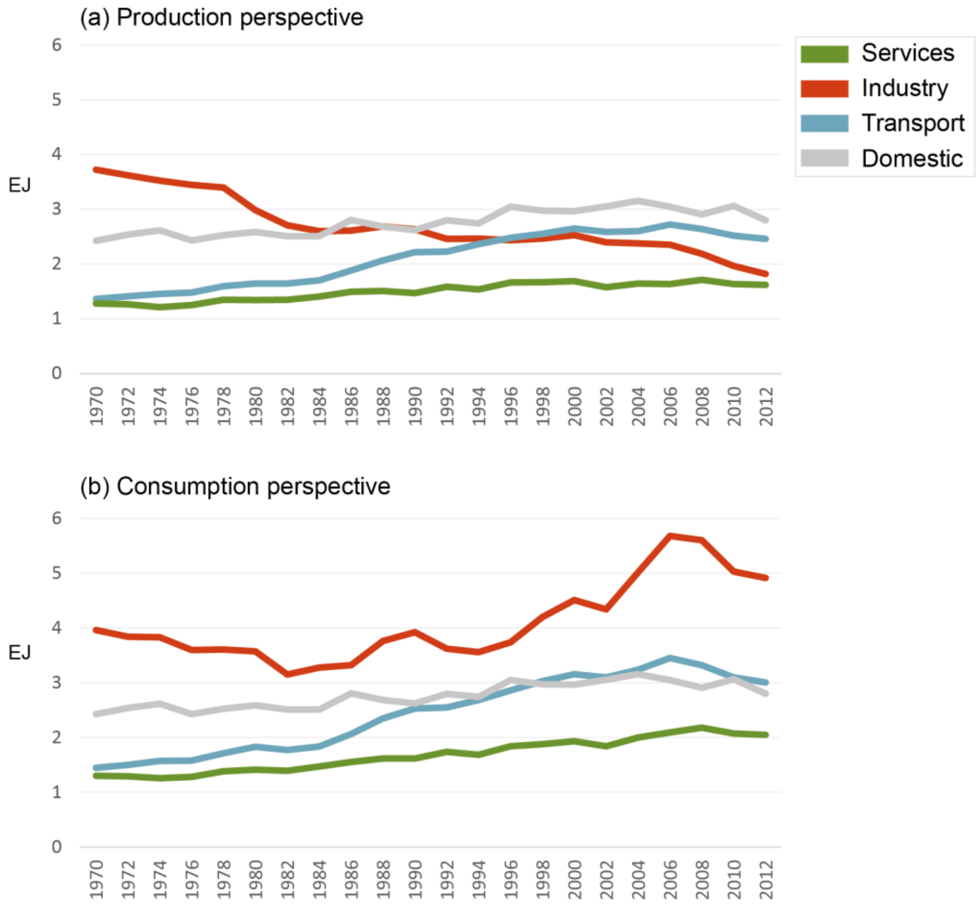

Figure 2a and 2b: Production and consumption based energy demand for the UK by sector (1970 to 2012)

Figure 2a demonstrates that between 1970 and 2013, three out of the four sectors increased in terms of energy demand, namely transport, services and domestic. These figures show the analysis from a production perspective. The most substantial increase was in transport with an 80% increase in energy demand. The only sector that reduced in energy demand was industry with a 50% reduction. Without this reduction, the UK's energy demand would have increased over this time period.

Figure 2b shows the energy demand of the UK from a consumption perspective. While industrial energy reduced by 50% within the UK, this was met with an increase related to consumption. In this case, energy demand from industry to satisfy UK consumption increases by 23%. In addition, industrial energy demand from consumption is now more than double UK based industrial energy demand.

This phenomena relates to the growth in trade of materials and products. Materials act as the carrier of industrial energy, allowing the outsourcing of energy intensive material production. This is precisely what has happened in the UK.

Therefore, the UK has not managed to reduce its energy demand. In fact, the energy demand of every sector has increased and it is only the accounting method that ensures energy demand, from a production perspective, has remained stable for the past 45 years.

One argument in defence of the lack of progress in energy demand reduction is the considerable economic growth that has been achieved over the past 45 years. The argument is proposed that the economy has grown by a multiplier of 2.5 with no increase in production energy demand. While the absolute energy demand is clearly the most important indicator, energy intensity indicators are often used to explore the level of decoupling.

Figure 3a and 3b explains the level of decoupling of the four high level sectors, for both production and consumption emissions. An appropriate “function unit” has been used for each of the four sectors. These being:

- Transport – energy demand per **passenger kms** or **tonne / kms** for freight
- Domestic – energy demand per **household**
- Industry – energy demand per **economic output**
- Services – energy demand per **economic output**

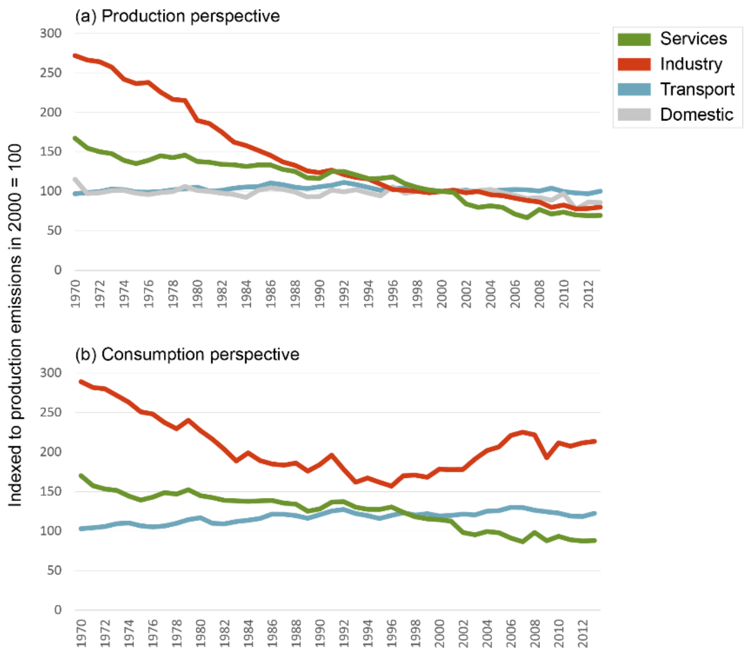

Figure 3a and 3b: Energy intensity of the UK from a production and consumption perspective (1970 to 2012)

The analysis shown in Figure 3a and 3b demonstrates that the level of decoupling between the relevant functional unit and energy is, in reality, a myth and relates to the adoption of an accounting system that excludes trade. Both figures show the level of energy intensity indexed to 2000 (where 2000 = 100). The production perspective shows relative decoupling in all sectors with the exception of transport. This does not mean that efficiency gains have not been made in these sectors. As previously explained, the efficiency of car travel has improved in that the energy use per vehicle km, primarily driven by EU legislation. However, this has not translated into a reduction in passenger kms which incorporates vehicle occupancy in the UK, which has continued to decline. An identical phenomena has occurred in domestic energy use where household occupancy has declined, equalling out the efficiency gains made from improvements to the infrastructure. Both transport and domestic energy cannot be significantly outsourced; however this is not the case for industry and, to some extent, for services.

When the consumption-based energy demand figures are included, the significant decline in industry energy intensity is not as steep between 1970 and 1990, demonstrating that part of the rate of decoupling can be explained by an increase in imports. In addition, between 1990 and 2013, there has been an increase in energy intensity, while the exclusion of traded energy shows a modest decrease. The energy intensity of transport flattens from a consumption perspective while the gains in the services are now more modest. In conclusion, trade explains a significant proportion of the decoupling and provides a more realistic picture.

Figure 5 links the energy system to the consumption of final products by households, government and capital investment with the aid of a Sankey diagram. Ultimately, all energy demand is a consequence of the demand for goods and services. Therefore, it is important when addressing absolute energy demand to have a detailed understanding of the energy required to deliver all household and government expenditure. This opens up the opportunity to explore how changing consumption could result in changing / reducing overall energy demand.

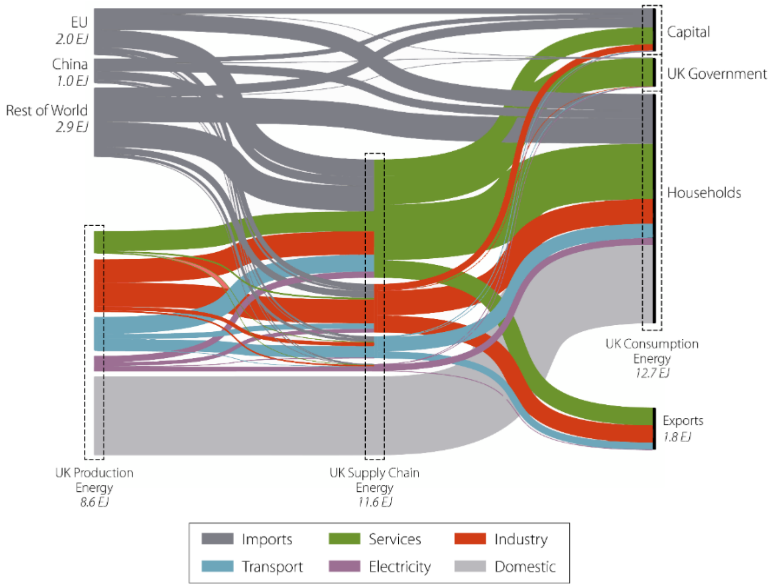

Figure 5 – Linking energy demand and production in 2013 (Sankey Diagram)

Figure 5 shows the imports and UK production of energy embodied in material products for both immediate and final consumption. The industrial system of the UK requires 8.6 EJ to produce its output. A small proportion of this energy is embodied in materials and products exported from the UK (1.8 EJ). The energy embodied in imports is substantially higher (6 EJ or three times that of exports). Approximately half the energy embodied in imports flow into intermediate demand (B to B relationships) while the other half are finished products purchased by households and government.

5. Invisible Energy Policy

Historically, gains in energy efficiency have failed to deliver a reduction in energy demand. In reality, energy demand has increased over the past 45 years and the false accounting of energy has created an illusion of relative decoupling. Therefore, while energy efficiency policies have the potential to slow down the level of growth, there is no evidence to assume that, in isolation, they can deliver a reduction in energy demand. The functional units adopted in the analysis above, incorporate wider societal changes such as changes in occupancy rates that demonstrate efficiency changes failed to deliver a reduction. However, the focus on energy demand policy remains an issue of energy efficiency. As Sachs (1999) suggests,

"There is nothing more irrational than running at maximum efficiency in the wrong direction.[26]"

As Sachs (1999) highlights, efficiency has three effects, these being rebound, volume and growth. As previously explained, rebound effects stimulate new expansion due to financial savings, volume effects occur from the expanding demand for new energy efficient products and growth ensures a continual increase in overall demand. In addition, energy demand driven by household and government expenditure for materials and products are greater than domestic energy demand. However, the attention given to materials and products in energy policy is almost non-existent. While the EU is delivering a "Circular Economy" package this has little to no relationship to energy policy and mainly focuses on waste management issues such as recycling. Therefore, an energy demand policy would differ significantly from energy efficiency policy. The four key variations would be:

- A focus on the energy service delivery and not purely on technological efficiency. This ensures that wider societal trends and practices are taken into account in energy policy.
- An approach that incorporates traded embodied energy to ensure that the reduction is real and not outsourced to other countries with potentially lower energy efficiency standards.
- An economy wide approach that recognises the need to incorporate limits (i.e. maximum energy demand levels) into energy policy. Without such a mechanism, rebound effects will occur. This requires an in depth appreciation of the effect of energy measures on prices and the inclusion of additional policies to counteract any rebound effects.
- A recognition that energy demand is driven by indirect activities such as planning, taxation, infrastructure development, health and employment patterns, to name a few. Energy demand is a government wide issue and not one to neatly sit inside one government department.

With this in mind, Table 1 provides a preliminary analysis to identify the differences between an energy efficiency and energy demand strategy for four areas of consumption.

Table 1 – Variations between an energy efficiency and energy demand management strategy

Sector / Consumption Category	**Energy efficiency approach**		**Energy demand management approach**	
	Measure	*Govt Policy*	*Measure*	*Govt Policy*
Aviation	Continual Improvement in engine efficiency.	Innovation funding and support for engine design	Introduce demand management approach to limit substantial increases in passenger kms by aviation	Avoid future airport expansion
Car travel	Reduce energy use per km for cars	Continue with EU Clean Vehicles Directive	Limit road space, reduce car parking availability, promote public transport	Road pricing, reduce network expansion, limit speed
Production of cars		Partly captured by EU ETS	Introduce resident parking, promote car clubs	Provide local authorities with the statutory measures to control local transport
Meat consumption	Improvement efficiency through new agricultural methods		Reduce meat consumption	Remove VAT subsidy on meat

Clearly, further analysis is required to appreciate the effectiveness of each of these policies. However, the table does illustrate how a change in focus would address many of the four key points identified above.

6. Conclusions, limitations and future research

In conclusion, the greenest form of energy is the energy that we don't need to produce. A focus on efficiency and a failure to take into account international trade, has led to the situation where the energy demand for the UK has continued to increase. This is despite the UK being one of the leading countries in the world in relation to climate policy. The greater the level of energy demand, the greater the burden of responsibility for climate change mitigation falls on supply side technologies and unproven negative emission technologies.

From a policy context, one government department has the responsibility to deliver energy efficiency improvements under the false notion that this will reduce energy demand. The composition of household consumption has been greatly influenced by a wide range of government policy, beyond the energy efficiency policies outlined by BEIS. Therefore, a government approach is required to address energy demand reduction.

There are a number of limitations involved in the analysis that help establish a future research agenda. This includes the production of energy analysis from a consumption perspective, the static nature of the analysis by using a MRIO approach and the need for a more comprehensive analysis of policy options. Further details on these three research agendas is provided below:

1. Combining energy vectors within an MRIO framework – there are a number of different approaches to combine energy within an MRIO framework and there has been little investigation into the use of different vectors such as primary energy, final energy consumption and exergy, for example. There are also a number of datasets that do not align due to differences in allocation systems and underlying assumptions. A more detailed analysis of these issues wold provide further robustness to the analysis.
2. Future projections of energy demand – the MRIO analysis provides a valuable static assessment of energy demand but fails to appreciate the future energy demand under a range of different circumstances. We are developing an economy-wide demand driven model to gain a stronger appreciation of the relationship between energy and economy and the economic effects of energy demand policies.
3. Policy appraisal of options – Table 1 merely provided some illustrative examples of energy demand policies. These options need to be investigated further and, with the use of the macro-economic model, a detailed understanding of their implications can be developed.

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[1] Corresponding author – j.r.barrett@leeds.ac.uk

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