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**Organisation:** UK Energy Research Centre

## Q1a. Are there any low carbon technologies or processes or major demand-side options which are not currently included within the scope of the model but that you consider should be in future?

**Your answer:**

**General Remarks**

As became apparent at the Chief Scientific Adviser's modelling workshop on September 28th 2010, the DECC Calculator sits alongside a number of long-established models, such as the DECC Energy Model and MARKAL, which provide insights into the possible future development of the UK's energy system. These other tools generally incorporate considerable detail on technology performance and cost, and are underpinned by both formal characterisations of the energy system and the interactions between its component parts, and the application of economic theory. In framing this response, we would like to draw out:

1. The unique capabilities and applications of the Calculator vis-à-vis other tools;
2. Ways in which the Calculator as it currently stands could be enhanced or improved (see Question 7); and
3. Areas in which it development would be less productive because the Calculator could not be enhanced without compromising its unique features

On point a), the main added value of the DECC Calculator in comparison to the other models is its relative simplicity and transparency. Rather than being a model in the formal sense, in that it is not based on any theoretical structures or hypotheses, it is essentially a carbon accounting tool that allows options and trade-offs to be explored. This means that it is accessible to more people than the other models, and allows people to experiment with questions such as: if not nuclear (or offshore wind or CCS) then what? These questions have been asked, and answered, before, but the DECC Calculator, in its online version, permits broader engagement with such questions than has previously been available. This is a valuable addition to what might be called the 'visualisation' (rather than modelling) capacity of the UK. The potential user base for the Calculator will probably be among more sophisticated and numerically proficient members of the public.

On point b), it is important that a careful perspective is maintained as to the potential capabilities of the DECC Calculator. In its relatively simple calculations, it abstracts from many of the issues, and bypasses interactions between the different components of the energy system that are incorporated in complex models. Some of these issues/interactions are detailed further in later sections of this response.

On point c), DECC should not do anything to the Calculator that undermines its key characteristics, i.e. simplicity and transparency. In particular, as identified at the CSA's energy modelling meeting, it should not seek to develop the cost side of the Calculator, partly because this dimension is well characterised in the other tools, and partly because, if it were done properly, it would largely obscure the simplicity of the DECC Calculator that is its main value. Nor would the Calculator be a useful tool for addressing issues such as path-dependence or technological lock-in.

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## Q2a. Does the range of alternative levels of ambition presented for each sector coverthe full range of credible futures? If not, what evidence suggests that the rangeof scenarios should be broader than those presented?

**Your answer:**

The sectoral analysis of the DECC Calculator gives evidence of much careful and painstaking work that should be of considerable use to the wider modelling community. It is particularly to be welcomed that the Calculator treats both the supply and demand sides. The exclusion of hydrogen from the possible sources of energy supply should perhaps be reconsidered. The treatment of the link between supply and demand, the energy network (through consideration of 'electricity balancing'), is cursory but probably adequate for the purpose of the Calculator. Much more detailed network models are required to gain more detailed insights into this important subject.

The modelling and scenarios evidence base (see response to Question 7) means we already know what many of the key high-level uncertainties are in respect of 2050 energy development. Three elements were identified in the Low Carbon Transition Plan (DECC, 2009) as:

1. The extent of electricity decarbonisation, and how this interacts with other sectors (transport, buildings and industry)
2. The extent of energy conservation and demand reduction, its drivers, its costs and its feasibility
3. The contribution of bio-energy, and its sustainable sourcing from the UK and abroad

Below we have carried a rough comparison between the DECC 2050 Pathways analysis and two separate modelling studies using UK MARKAL: UKERC Energy 2050 (UKERC, 2009) and the CCC first report to Parliament (CCC, 2008). We have focused on Pathway Alpha, but the conclusions apply broadly across the full set of Pathways. For obvious reasons, cost aspects could not be compared.

The high-level conclusions we reach are:

1. The levels of final energy demand in the Calculator Pathways are systematically higher than those in most other published scenarios. In general, for a given $CO_2$ reduction, the Calculator places greater emphasis on supply side (especially electricity) de-carbonisation than do most other scenarios.
2. Scenarios published by others have very mixed messages about both the scale and role of bio-energy in the energy system. This is because the models underlying the scenarios explore a complex set of interactions between assumed cost of deployment in different sectors and availability. The Calculator results can be more directly connected to the input assumptions and hence the key trade-offs need to be explored outside the Calculator tool.

Building on this latter point, a difference between the DECC Calculator and more conventional energy system models, is that the DECC Pathways are not the result of any decision criterion except for a 2050 emissions target, and therefore rely directly on the choices of technology made by the Calculator user. This can be useful in generating insights into the trade-offs between the various technologies in terms of their carbon reductions (less of one low-carbon technology requires more of another) but it produces no further insights into which technological mix might be preferable, or why (beyond the preferences of the inputting user). This compares with the cost-minimising philosophy that underpins MARKAL and other models.

The following discussion identifies in more detail key differences between the Calculator Pathways and other scenarios.

#### a.Electricity decarbonisation

All the DECC pathway scenarios have a considerably larger electricity systems than any of the UKERC and CCC scenarios by 2050 (~2000 PJ versus <1500 PJ in 2030 and ~3000 PJ versus ~2000 PJ in 2050). The major contribution to this new demand for electricity comes from the industrial sector, a change not seen in the UKERC and CCC scenarios. In UK MARKAL based scenarios, industry tends not to electrify with a preference for energy service demand reduction (in response to the increasing price of energy carriers under low-carbon scenarios), adoption of more efficient processes and move to natural gas. Residential gas use concurrently decreases as the residential sector moves to electric heating.

However, in the industrial trajectories of the Calculator's the relative contribution to decarbonisation of the industrial fuel mix, process improvements and level of CCS is not clearly specified. In UK MARKAL, industrial fuel mix and the adoption of industrial CCS, is clearly distinguished and demand-led on the basis of costs, allowing more detailed insights into industrial decarbonisation pathways.

The Calculator is limited in its ability to represent the uncertainties surrounding future decarbonisation, and path dependency and the possibility of technology lock-in. For example, using the interface, a user can arrive at a combination of demand and supply measures that meet the target. However, if the emissions target is then increased in severity, there is no means available using the DECC Calculator to measure the ease of meeting this more stringent target. It is also very difficult to gauge the path dependencies inherent in a particular set of scenarios assumptions in a consistent manner.

#### b.Energy demand reduction and efficiency improvements

Under the Alpha scenario, final energy demand remains relatively constant through to 2050 at ~7,000 PJ. The UKERC and CCC scenarios show a radically different picture of 2050, with final energy demands of ~4,500 PJ and ~3,500 PJ respectively. Even accounting for the exclusion of international aviation and shipping (accounting for ~1,200 PJ in 2050), there remains a marked difference. UK MARKAL studies show that final energy demand can be reduced while the demand for energy services increases, through the adoption of i) more efficient technologies and ii) energy conservation measures such as insulation. The studies further show that energy service demand growth slows as energy consumers respond to price increases. The effects of these changes in the structure of energy use and energy supply are then measured in a number of ways. These include: $CO_2$ emissions, total cost of the energy system or change in welfare cost etc.

Efficiencies and other parameters of generation plant are fixed throughout the Calculator's time horizon, thereby ignoring the effects of improvements in existing and new technologies over time. Indeed, the reference case in the calculator does not include many efficiency improvements that you would expect to see from a perspective of industrial competitiveness or economic efficiency. By not including a price response, the Calculator misses the downward pressures on energy service demands that will be induced by the rising cost of $CO_2$ emissions. This can be partially remedied outside the modelling tool by adjusting input assumptions.

In contrast, the transport sector in the Calculator is quite well specified with improving vehicle efficiency over time. However, the scenarios' fixed split of vehicle technologies is a weakness. Both International Aviation and Shipping could benefit from more detailed treatment given their relatively large impact on energy use in the transport sector.

#### c.Bio-energy

Bio-energy can displace many hydrocarbon based fuels, often at a lower efficiency than a high quality hydrocarbon, but with a benefit for net $CO_2$ emissions. Bio-energy chains are very complex and there are a huge number of possible bio-energy resources, conversion processes and end-uses. The conflict between food and fuel is another complication, with corresponding impacts upon land-use. To assess the opportunity cost of biofuels, it is essential to compare the whole system cost of biofuels with alternative fuel options.

The transport sector in particular demonstrates the complex interactions that take place between technologies based upon the numerous attributes that define them. These include among others, investment costs, operating costs, technical efficiency, availability, lifetime, fuel requirements and so on. The UKERC scenario demonstrates a vehicle fleet that decarbonises from 2030 primarily through consumption of bio-diesel (~300 PJ), bio-ethanol (~400 PJ) and electricity (200 PJ) by 2050. The CCC scenario showed a different picture for future transport, with a portfolio of vehicle fuels including gaseous $H_2$ (~300 PJ), biodiesel (~200 PJ), electricity (~200 PJ), and final energy demand decreasing to around 1,200 PJ. In contrast, the Alpha scenario accommodates very limited penetration of both electric and bio-product vehicles with the majority running on conventional liquid fuels.This appears to be due to a combination of constraints on the availability of bio-fuel resources, with maximum imports at ~1,000 PJ in 2050 and domestic resources limited to ~500 PJ overall in 2050 and few very discrete technology pathway choices that cannot reflect all possible outcomes.

We are concerned that the fixed splits between bio-products, across the four input scenarios, unnecessarily restrict the use of these bio-products in the energy system.  While there are physical constraints on conversion capacities, resources and an upper bound on the efficiency with which conversion can take place, we feel that these have been implemented in the Calculator with unnecessary severity, so that some feasible bio-energy pathways do not emerge.

**References**

CCC (2008) Building a low-carbon economy – the UK's contribution to tackling climate change, Climate Change Committee inaugural report, London

UKERC (2009), Energy 2050 Synthesis report, UK Energy Research Centre, London. www.ukerc.ac.uk

**Upload file:** Not Answered

## Q2b. Do the intermediate levels of ambition (levels 2 and 3) provided for each sector illustrate a useful set of choices, or should they be moved up or down?

**Your answer:**

We have not had the opportunity to explore the many specific assumptions in depth. However, a fairly cursory look suggests that more effort could be put into ensuring that a consistent approach is used, as far as possible, across the wide range of supply and demand side technologies. We have, for example, noted above that the reference case in the Calculator does not include many efficiency improvements that you would expect to see from a perspective of industrial competitiveness or economic efficiency. However, this question merits a detailed response which we have not been able to address.

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## Q2c. The 2050 Pathways Calculator currently describes alternative directions of travel rather than different levels for some sectors where changes reflect a choice rather than a scale. Is this a suitable approach and clear to users?

**Your answer:**

UKERC has not submitted an answer to this question.

**Upload file:** Not Answered

## Q3a. For each sector, are the input assumptions and the methodologies applied to those input assumptions reasonable?

**Your answer:**

We have not been able to address this comprehensively. We include some observations on domestic lighting where the Calculator draws on previous UKERC work.

**Specific note on Domestic Lighting**

Work by the ECI (Boardman 2007) has been cited in the analysis with respect to domestic lighting and we would welcome the opportunity to provide further background and updates to the underlying UKDCM data.

A later report (Curtis, 2009) provides updated results and a refinement of the stock and demand model used to estimate the energy savings that would result from a shift to the use of solid-state lighting in the domestic sector by 2050. The scenario described would be most similar to the Level 4 trajectory of the Pathways Analysis.

The report looked at recent trends in household demand for light (in lamp lumen hours per year) together with the luminous efficacies (lumens per watt (lm/W)) of the mix of lighting technologies used to provide this demand. For the year 2007, the total energy used for domestic lighting was 17.1TWh at an average efficacy of 16.5lm/W. A complete shift to solid-state lighting (with household lighting reaching an average efficacy of 200lm/W by 2050), would, taking into account factors such as population growth, lead to a reduction in energy use of 88% (to 2.0TWh for the year 2050).

| | 2007 | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Domestic Lighting (TWh)** | **17.1** | **13.2** | **7.3** | **6.0** | **4.8** | **3.3** | **2.2** | **1.9** | **1.9** | **2.0** |

***Notes***

- The final figure of 200lm/W was reached by 2040 using a diffusion model based on past and predicted trends in costs and technology for devices capable of providing white light of a quality (CRI and CT) and price equivalent to that of a filament bulb. The figure of 150lm/W used previously (ECI 2007) was for the year 2020 at a cost bringing the technology to the cusp of 'early adopters'/'early majority' quintiles (after Beal and Rogers, 1958). Current 'innovators' are catered for in part by a US initiative, the L-Prize, with a reward for any manufacturer that can bring  90lm/W solid-state emitters of near-filament-quality white light into sustainable commercial production.

- Throughout the modelling, luminous efficacy was considered with respect solely to bare light emitters. With solid-state lighting this is of particular importance, since, unlike with traditional light emitters (bulbs and tubes), solid-state lighting can be designed without recourse to diffusion by luminaires or lampshades. Luminaire efficiency, or its converse, utilization efficiency, relates the light output from a given emitter to that absorbed by diffusers: *The difference between this utilization efficiency for LEDs versus conventional sources can be a factor of two, or even more in the case of task lighting* (Krames, 2007). Accounting for this quality could provide for (a) a 2050 efficacy as low as 100lm/W with the same overall reduction in energy use; (b) the same 200lm/W efficacy with double the reduction.

***References***


Beal, George M., and Everett M. Rogers. 1958. The Scientist as a Referent in the Communication of New Technology. *The Public Opinion Quarterly 22*, no. 4 (Winter, 1959): 555-563.

Boardman, B. 2007. Home truths: a low-carbon strategy to reduce UK housing emissions by 80% by 2050. *Research report for The Co-operative Bank and Friends of the Earth.* http://www.eci.ox.ac.uk/research/energy/downloads/boardman07-hometruths.pdf

Curtis, D. 2009. Predictions for the contribution of residential lighting to the carbon emissions of the UK to 2050. *Conference paper*. EEDAL, Berlin, June 2009. http://www.eci.ox.ac.uk/publications/downloads/curtis-EEDAL09.pdf

Krames, M.R., *et al*. 2007. Status and Future of High-Power Light-Emitting Diodes for Solid-State Lighting. *Display Technology, Journal of* 3, no. 2: 160-175. doi:10.1109/JDT.2007.895339


**Upload file:** Not Answered

### Q3b. As regards specific sectors:Are the bioenergy conversion routes used in the model accurate, or are there more efficient routes for converting raw biomass into fuels?

**Your answer:**

UKERC has not submitted an answer to this question.

**Upload file:** Not Answered

### Q3c. As regards specific sectors:Can the model’s assumptions on wave resource be improved, for example regarding the length of wave farms, their distance from shore, the efficiency ofdevices, constraints from other ocean users, and other assumptions?

**Your answer:**

UKERC has not submitted an answer to this question.

**Upload file:** Not Answered

### Q3d. As regards specific sectors: Can the model’s assumptions on tidal stream resource be improved, for example regarding the method for assessing the resource at specific locations, and the scaling up of individual devices into an array?

**Your answer:**

UKERC has not submitted an answer to this question.

**Upload file:** Not Answered

### Q3e. As regards specific sectors: Is there any evidence that would help build an understanding of the potential impact of long term spatial development on transport demand, and how could this be accounted for in the model?

**Your answer:**

UKERC has not submitted an answer to this question.

**Upload file:** Not Answered

### Q3f. Due to uncertainties in the evidence base on energy demand and associated emissions, the model currently sets out only one level of ambition for the future UK share of international shipping. Is there any evidence you could contribute to help build a greater understanding of the potential shipping trajectories?

**Your answer:**

UKERC has not submitted an answer to this question.

**Upload file:** Not Answered

### Q3g. Could the relative roles of coal and gas out to 2050 vary from the assumptions shown in this work, and if so, how?

**Your answer:**

UKERC has not submitted an answer to this question.

**Upload file:** Not Answered

### Q4a. The introduction to the report sets out some of the implications and uncertainties common to the illustrative pathways. Does this list cover the key commonalities? If not, please identify other common implications and uncertainties and provide evidence as to why these are key conclusions from the analysis.

**Your answer:**

UKERC has not submitted an answer to this question.

**Upload file:** Not Answered

### Q5a. What criteria should be taken into account in understanding the impact and relative attractiveness of pathways?

**Your answer:**

The DECC Pathways depend entirely on the input choices and preferences of the user of the Calculator. It has no decision criteria that can distinguish between the desirability of Pathways beyond this. The most common criterion in other energy system models is cost, with a preference for least-cost pathways. The UKERC Energy 2050 project also performed extensive off-model calculations to distinguish between the non-carbon environmental impacts of different energy systems, the cost benefits of accelerated technological development, the interactions, synergies and trade-offs between the policy objectives of decarbonisation and energy security and the effects of different levels of lifestyle changes. The calculations were then transferred to the MARKAL model to show their implications for the UK's energy system as a whole, especially in terms of their impact on cost and social welfare. It is not clear that the DECC Calculator is able, at its current stage of development, to represent this wide range of different possibilities and issues.

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### Q6a. Can you suggest a methodology by which the wider cost implications of choosing one pathway over another could be accurately reflected, and any relevant findings from such an approach?

**Your answer:**

As noted in the first section of this response, there are a number of other UK models in the public domain that provide a comprehensive treatment of technology and energy system costs, that take into account the complex interactions between different parts of the energy system, and it does not seem a good use of public funds to duplicate this facility in the DECC Calculator.

**Upload file:** Not Answered

### Q7a. Do you have any further suggestions for refining the 2050 Pathways Calculator?

**Your answer:**

We make a small number of suggestions for enhancements and then set out some notes on the evidence base available for refining the more detailed assumptions.

Suggestionsinclude:

1. Conducting a thorough review of the level 1/2/3/4 assumptions to ensure a greater consistency of approach across the various supply/demand side measures.

2. As the Calculator is “bottom-up” rather than taking a holistic view of the energy system, introducing a set of consistency checks to ensure that specific assumptions made by users do not conflict with assumptions made about other parts of the energy system. If users were to be alerted to potential conflicts it could enhance the educational value of the tool.
3. Given the relative simplicity of the Calculator, it may be possible to exercise it within a “Monte-carlo” framework whereby uncertainty about a range of input assumptions could be reflected in outputs. Outputs could then be screened for: a) internal consistency; and b) policy criteria (e.g. $CO_2$ emissions) to reach conclusions about measures that are robust against a range of assumptions.

**Note on evidence base for DECC 2050 Pathways**

There is a rich and large evidence base on modelling and scenario studies on energy futures through to 2050. In terms of major international studies of energy sector decarbonisation, the Stern Review (Stern, 2006) the Intergovernmental Panel on Climate Change’s 4th assessment report (IPPC, 2008), the Innovation Modelling Comparison project (Edenhofer et al, 2006), the studies of the Energy Modelling Forum (e.g., van Vuuren et al., 2006), the Low Carbon Societies project (Strachan et al., 2008), and the International Energy Agency’s Energy Technology Perspectives (IEA, 2008) are the highest profile of a global analytical effort. A range of energy-economic modelling tools, from technologically detailed partial equilibrium optimisation and simulation models, to general equilibrium models of the energy sector’s interactions with the wider economy have been utilised. The DECC Calculator provides a much simpler approach suited for public engagement, but there would seem to be little point in developing it to duplicate the modelling capability which already exists in the UK and which has already been used to give policy support for every major energy UK energy policy document over the last few years. This has included the 2003 Energy White Paper, the 2007 Energy White Paper, the 2008 Energy Bill, the regulatory impact assessment of the 2008 Climate Change Bill, the 2009 Low Carbon Transition Plan, and the inaugural (2008) and successive budget reports (2009-2010) of the Committee on Climate Change. As already noted, further major publicly-funded academic research efforts – such as the UKERC Energy 2050 project (UKERC, 2009) – have heavily utilised energy modelling tools to develop long term insights on the resource, technology, infrastructure and behavioural changes required to reach long term decarbonisation and energy security goals. In this body of UK focused work, selected energy models include:

- Energy systems optimisation models (UCL’s UK MARKAL, with macro, elastic demand and stochastic variants)
- Macro-economic (and macro-econometric) models, including the HM Treasury macro model, Cambridge Econometrics’ MDM-E3 and Oxford Economics’ OIEM
- Network models including Redpoint’s electricity dynamics modelling, University of Manchester’s CGEN
- Sectoral models including the buildings and transport models of ECI, University of Oxford
- Integrated assessment models, including PAGE 2002, from the University of Cambridge

As well as a modelling evidence base there is also a broader energy scenarios evidence base. Table 1 below lists major UK relevant studies (Source; Hughes and Strachan, 2010).

These studies illustrate a number of key elements which are widely considered essential for an underpinning policy analytical framework:

- A rigorous model methodology: whether this is maximisation of economic welfare, optimisation of energy system costs, econometrically derived relations to calibrated input variables, or clear decision rules on investment and behaviour.
- Accounting for interactions between different, resources, sectors, as well as the energy sector vs. other sectors of the economy
- A central positioning of costs as drivers of energy service provision, and of the calculation of resulting economic implications
- The ability to implement alternative policy specifications, including taxes and other pricing mechanisms, standards and other regulatory measures, and R&D support and other innovation measures
- A depiction of the interrelation of the UK energy system with international drivers on policy, technologies, and resources
- A clear methodology to deal with temporal detail, and the issues of path dependency in the long-term evolution of the energy system
- A clear methodology to deal with uncertainty, either through formal probabilistic or stochastic techniques, or at the least via systematic what-if parametric analysis

The user interface of the DECC Calculator is easy to use and clear, mainly due to the simplifications made in establishing the four ‘effort levels’ to make up the supply and demand sector scenarios. It is recognised by the developers that the Calculator requires careful validation of inputs because it is possible to select mutually exclusive combinations of technology. A related problem is also a result of the Calculator’s structure. It is quite possible for a user to change an input trajectory and see very little change in results. It is then difficult to see *why* there is no change in output. The simplicity of the user interface is possible because of the Calculator’s simplifications of what is in reality a complex system with multiple feedbacks, inter-sectoral relationships, and upstream/downstream trade-offs.

**Table 1**: UK (and selected international) long-term energy scenario studies

| SCENARIO EXERCISE | AUTHORS, DATE | AFFILIATED ORGANISATIONS | SCOPE OF STUDY |
|---|---|---|---|
| **Trend Driven Studies** | | | |
| Special Report on Emissions Scenarios | Nakicenovic et al (2000) | Intergovernmental Panel on Climate Change | Global, energy use and land use change |
| Foresight Scenarios | Berkhout et al (1999) | Office of Science and Technology / Foresight Programme | UK society |
| Socio-economic scenarios for climate change impact assessment | UKCIP(2000) | | UK society |
| Scenario Exercise on Moving Towards a Sustainable Energy Economy | IAF, Virginia (2004) | IIR, University of Manchester | UK energy and society |

| | | | |
|---|---|---|---|
| Transitions to a UK Hydrogen Economy | Eames and McDowall (2006) | Supergen UK Sustainable Hydrogen Energy Consortium | UK energy system |
| Electricity Network Scenarios for Great Britain in 2050 | Elders et al (2006) | Supergen Future Network Technologies Consortium | UK electricity system |
| Electricity Network Scenarios for Great Britain in 2050 (LENS project) | Ault et al (2008) | Ofgem | UK electricity system |
| **Technical Feasibility Studies** | | | |
| The Changing Climate | RCEP (2000) | | UK energy system |
| Decarbonising the UK | Anderson et al (2005) | Tyndall Centre | UK energy system |
| The Balance of Power- Reducing $CO_2$ Emissions from the UK Power Sector | ILEX (2006) | World Wildlife Fund | UK electricity system |
| Decentralising UK Energy | WADE (2006) | Greenpeace | UK heat and electricity |
| A Bright Future: Friends of the Earth's Electricity Sector Model for 2030 | FOE (2006) | | UK electricity sector |
| Powering London into the 21st Century | PB Power (2006) | Mayor of London, Greenpeace | London, heat and power from buildings |
| Technical Feasibility of $CO_2$ emissions reductions in the UK housing stock | Johnston et al (2005) | Buildings Research Establishment | UK, energy demands from domestic buildings |
| 40% House | Boardman et al (2005) | Environmental Change Institute, University of Oxford | UK, energy demands from domestic buildings |
| **Modelling Studies** | | | |
| UK MARKAL (Energy White Paper etc) | Strachan et al (2007) | BERR, DEFRA, Policy Studies Institute, AEA Technologies | UK energy system |
| Energy 2050 | UKERC (2009) | | UK energy system |
| Japan Scenarios and Actions Towards Low Carbon Societies | Fujino et al (2008) | NIES, Japan | Japan energy system |
| World Energy Outlook | IEA (2008a) | | Global energy systems |
| Energy Technology Perspectives | IEA (2008b) | | Global energy systems |
| World Energy Technology Outlook | European Commission (2005) | EU | Global energy systems |

Inevitably, in constructing the calculator, the developers have come across similar problems to those faced by the global community of energy system modellers. Energy system models such as MARKAL use the concept of energy service demands to characterise the specific services obtained by energy consumers. This abstraction allows final energy demands to be disentangled from the actual service requirements energy users have of energy (such as 'light' or 'warmth'), via a pool of demand technologies that convert energy commodities into energy services. In turn, these energy commodities may be products of transformations by upstream technologies. In the DECC Pathways Calculator, the demand sector switches between energy service demands (for transport), final energy demand, efficiency measures, future technology choices, supply (and price) dependent technology pathway choice and behaviour change. This makes it difficult for the DECC Pathways to generate consistent and coherent insights into how future uses of energy develop.

**References**


CCC (2008) *Building a low-carbon economy – the UK's contribution to tackling climate change*, Climate Change Committee inaugural report, London

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Edenhofer O., Lessmann K., Kemfert C., Grubb M., and Kohler J., (2006) *Induced Technological Change: Exploring its Implications for the Economics of Atmospheric Stabilization*: Synthesis Report from the Innovation Modelling Comparison Project, The Energy Journal, Special Issue #1.

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van Vuuren D., Weyant J. and de la Chesnaye F. (2006) *Multi-gas scenarios to stabilize radiative forcing, Energy Economics*; 28(1), 102-120.


**Upload file:** Not Answered

**Q7b. Could the 2050 Pathways Calculator be improved to reflect the fact that the level of ambition for some sectors will depend on local preferences? Could thePathways Calculator be improved such that the inherent degree of individual and**

**local choice in a chosen pathway were clear?**

**Your answer:**

UKERC has not submitted an answer to this question.

**Upload file:** Not Answered