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Supplemental Review for the Committee on Climate Change (CCC)

MARKAL-MED model runs of long term carbon reduction targets in the UK Phase 2

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Introduction

This supplemental review focuses on the CCC commissioned set of follow-up runs undertaken by AEA Technology using the MARKAL Elastic Demand (MED) model and reported in "*MARKAL-MED model runs of long term carbon reduction targets in the UK - Phase 2*", October 2008. This review discusses the choice of the follow-up runs, and discusses each in turn. This covers the issues addressed, issues still outstanding, and interpretation by policy-makers.

The AEA report confirms that MED is an appropriate and powerful modelling environment for undertaking systematic scenario analysis of long-term decarbonisation pathways. Once again the report itself is well-written, providing a balanced discussion of the core findings and model trade-offs.

Overview comments on follow-up report

It is appreciated that additional runs needed to be prioritised in accordance with available time and to reflect the changing policy requirements for analytical insights. As such only a subset of the original review's suggested additional runs have been addressed. The restricted transport technology diffusion assumptions partially address the issue of low end-use discount rates, although not for buildings and industrial sectors and not for all later periods. Similarly the sensitivity removing transport and electricity hurdle rates gives a level mitigation comparison across all sectors, albeit at a social discount rate.

Of the suggested runs that were deemed too complex, the dynamic multi-stage and extension to stochastic case fall into this category. Despite advancing the 2-staged investment approach to include non-electric technologies (e.g., hydrogen production) and running additional scenarios, these results generate only modest additional insights. Other complexities that include alternate treatment of intermittency using a peak constraint (capacity credit) approach, and cumulative constraints fixed to 2000-2010 levels, are covered in the soon-to-be-released UKERC Energy 2050 project.

Of the suggested runs that were deemed as being best handled off-model and then to gauge the direction and magnitude on MED results; the alternate international CO_2 prices, demand elasticities and minimum demand levels, enhanced bio-energy imports, and lowered electricity build rate constraints for all technology classes fall into this category. However I still believe that these represent interesting insights in themselves, although appreciate the volume of additional information that these would entail to be communicated.

Of the suggested runs flagged by the review as being not necessary, I note that high-high fossil fuel prices and electricity technology sensitivity runs have been carried out. Of all the runs the former is the most problematic in terms of concept and model implementation.

All runs in this report are carried out with alternate transport diffusion assumptions. This makes the scenarios in the Phase 2 and 1 reports not directly comparable in terms of specific numbers but likely still in insights. Hence they can all be communicated to policy makers (with an appropriate caveat).

Last, I note and welcome that all resulting energy costs graphs and tables are now in terms of welfare (consumer plus producer surplus) instead of energy systems costs. This make best use of the MED partial equilibrium framework. Some greater discussion on energy service demand changes would be useful to cover this important behavioural response to rising prices from decarbonisation.

Alternate technology transport assumptions

The restrictions on near- and mid-term transport hybrid technologies appear reasonable, although could benefit from a source for the assumptions (e.g., the DfT?). I note however that a similar approach could have been undertaken for building conservation options.

The 2020 period higher costs and later period reduced welfare costs are in large part due to investments in mitigation efforts in other sectors - many of which are long-lived.

It is worth mentioning here the role of build rates - in specific periods, (gas in 2020, coal CCS in 2030, gas CCS in 2040, wind in 2050) build rates breach 2GW per annum. None of these are maintained to mimic an equivalent to a 2nd "dash to gas", but constraining them would produce a smoother evolution of the electricity portfolio.

Higher renewable energy targets

The 32% renewable electricity share is lower than the 40% run in Phase 1, which itself still fell short of total UK renewable final energy target. The earlier 40% run gave greater magnitudes but similar directional trade-offs in terms of reduced electricity production and increased CO_2 and welfare costs.

Further interesting runs could look at achieving energy sector wide renewable energy targets including constraints in the transport and heat sectors. However this would require further work on the availability and costs of domestic and imported bio-resources. A second interesting run would be to look at alternate peaking constraints and electricity system operation. Both of these ideas were flagged in the first review.

Higher fossil fuel assumptions

Conceptually, the assumption of $150/barrel oil and related natural gas and coal price rises is the most problematic in the entire analysis. I do not agree that recent short-term restriction of supply and demand responses coupled with speculative activity should be a basis for long-term projections of fossil fuel prices. Furthermore, that the projections are now a flat line post-2015 apparently removes a insightful argument that rising developing country demand is steadily forcing up prices. Writing at the end of October 2008, oil has fallen to $65/barrel, and is expected to go lower as economic activity slows. Lastly one has to question why oil prices would remain so high if the UK and other countries were massively decarbonising their economies?

There is also a problem in how the model handles these extreme prices - although this is a function of the model design and not the analysis by AEA. The model contains BERR estimates of costs of production for future UK domestic resources that would be triggered in the event of rising prices. These tranches are designed to be triggered individually under a forecast range of fossil fuel imports. I am a little confused in what metrics the numbers in the report are, but assuming they are £2005 and GCV, the table below summarizes the range of costs

(£/GJ)	High-high price	'usual' MED import price - 2010-2050	Domestic higher tranches
Oil	12.0	5.2 - 6.4	(#5-#10) - 5.2, 7.0, 7.9, 8.8, 9.6
Gas	8.8	3.8 - 4.9	(#6-#9) - 3.8, 4.3, 4.8, 5.3
Coal	2.7	1.1 - 1.6	(#5-#6) - 1.15, 1.25

You will see that the high-high prices swamps the domestic tranches and hence triggers them all. This is particularly a problem as the higher cost domestic tranches have a much larger (cumulative) constraint. It is also a much larger problem for oil as its domestic tranches are larger and its later period demand is falling the most (under CO2 constraints). There is a bound in the model to use fossil imports to some degree until 2025 but after this imported oil is not chosen, while imported gas is not selected post 2030 and imported coal post 2040. Hence the 'high-high' fossil fuel runs are not really high fossil fuel runs, and hence this drives the modest differences we see in the results. Note that this price limiting process also happens under standard model results but to a **much** less degree with the imported/domestic difference being small, and only intermediate new domestic tranches being triggered before the model switches back into imports.

Following on from the above it is not surprising that quite modest changes are seen in the model; this is a reflection of higher oil and gas prices around 2020 (e.g., in higher welfare costs). Another factor is in more expensive gas though 2050 (which reverts to imports) and results in the demise of gas CCS, as well as in greater electricity production as buildings and industrial electricity and gas boilers compete.

I would recommended either removing this section entirely or rerunning the model with all higher domestic oil, gas and coal tranches switched off.

Inclusion of international aviation

This sensitivity is highly policy relevant and illustrates that cumulative welfare costs of £189Bn represents a 50% increase in meeting the -80% target. This would be even higher if an indirect multiplier is used (e.g., for the IPPR M-M analysis we used 2.5 to account for non-CO radiative forcing). I do not understand why emissions are attributed to bio-kerosene but not to other bio-fuels or to uranium mining etc. Nor do I understand why this is at a 50% cost level. Both these assumptions need to be explained and justified.

Other sensitivities

<u>Low carbon technologies</u>

Once again there is only a small cost difference between CCS and nuclear emphasizing the potential and uncertainties on both this base-load low carbon technologies.
In the no-CCS no-nuclear runs, wind grows to 42% of generation - this is well below the 60-70% finding in the EWP runs and reflects the roles of the added grid balancing cost approach. However further work in intermittency and peaking constraint treatment would be warranted. In addition, the role of peaking electricity capacity (natural gas) should be noted. More important is to flag up the very large cost increases (to £220Bn) discounted welfare of no-CCS no-nuclear runs.
One interesting further run would be to restrict CCS, nuclear and wind to see how/if the model react with no major low carbon electricity technology.

<u>Alternate constraints</u>

These runs are most interesting to see how the model performs at 85% and 90% constraint levels. At a 90% constraint level, CCS is limited by its residual CO2 emissions rather than the storage reservoir

capacity. Note as the model switches to larger-scale hydrogen from electrolysis and especially imports, the uncertainties in these pathways and costs increase.
The welfare cost increases are modest but this reflects the discounting of costs and how the tougher targets only really give high costs by 2050 - this is shown by the marginal CO2 price rising to £330/tCO2.

Additional 2 stage runs

As noted earlier I am not sure what these add to the earlier Phase 1 runs. Perhaps relegate to an appendix?

Additional runs

While I welcome the 3.5% flat discounting it is vitally important to explain what this means to make welfare, CO2 prices etc comparable. This run is saying that consumer preferences change, and provision of information and other barriers are resolved to hence make socially optimal decisions. This **only** happens in a low carbon world (i.e., not the reference case) - hence costs are much lower than otherwise. Also note that hydrogen production is likely driven by removal of hurdle rates on hydrogen transport technologies (again via removal of uncertainties).

Applying the constraint from 2040 only gives a logical model response, but the perfect foresight assumption is limiting. Again one probably needs to double check achievable build rates of key decarbonisation technologies. Here would be an ideal extension into true stochastic modelling with two states of the world - one where a CO_2 constraint was expected and one where decision makers thought that government and society's resolve would change/ebb and the CO" constraint would not happen (or happen later).