<u>E.ON in the UK response to DECC Call for evidence on 2050 Pathways Analysis</u>

1. **Scope of model:**
(a) 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?

There do not appear to be any current low carbon generation technologies which have been omitted from the scope of the model. On the demand side we would propose that greater attention could be paid to consumer education. We would also propose that as the model is developed there is significantly more focus on the role that smart grids and demand side management will have in the future.

2. **Scope of sectors:**
(a) Does the range of alternative levels of ambition presented for each sector cover the full range of credible futures? If not, what evidence suggests that the range of scenarios should be broader than those presented? (b) 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?

In general we would recognise and concur that each of the levels described within the pathways analysis are scientifically possible, however we have attempted to highlight our rationale for levels of effort which should perhaps be considered as highly improbable. These can result from numerous constraints including; financial, skills, political acceptance, sustainability and technological development. In addition we have also tried to rationalise why we believe lower levels of effort are credible and where possible indicate our expectation of what can realistically be delivered. We have attached the following detailed analysis for each of the sectoral trajectories.

<u>Detailed sector trajectories;</u>

A. Lighting and appliances

Level 1: This scenario is possible but unlikely. Most lighting and appliance manufacturers are European or Global companies so the market for these products will not be driven solely by demand from the UK. For this scenario to be credible, i.e. demand increase, would require stagnation of EU energy policy on efficiency improvements in lighting and appliance technologies.

Level 2: This is a credible scenario, with LED lighting technology having 100% penetration by 2050

Level 3: Credible

Level 4: Credible but stretching

Other Comments: The market for lighting and appliances is a global one and hence the technology advancement is likely to be driven at least by EU policy.

B. Transport

Level 1: This is credible

Level 2: This is credible

Level 3: The assumptions suggest the introduction of hydrogen fuel cell vehicles (accounting for 20% of car journeys). However the rationale is less clear. We question the credibility of having a scenario where hydrogen and electric fuelled electric vehicles co-exist. This is because the infrastructure to support 20% of car journeys from hydrogen fuel feels sub-scale, (i.e. a national infrastructure to support a small portion of the car fleet) would be economically unattractive. A national electric charging infrastructure and a hydrogen fuel infrastructure co-existing seems unlikely. It is more likely that there will be one winning fuel rather than two. We believe electric vehicles are the more sustainable and efficient in a low/zero carbon generation world.

Level 4: To build on level 3 comments, the most energy efficient scenario would not include hydrogen fuelled vehicles.

Other Comments: The comments above relate to car passenger transport only.

C. Industry

Trajectory A: The general assumptions within this trajectory appear to be reasonable.

Trajectory B: The general assumptions within this trajectory appear to be reasonable.

Trajectory C: Trajectory C is thought to be a little ambitious when it comes to decline of greenhouse emissions. This is because in the absence of a global climate deal any additional efficiency measures are likely to incur large capital investments which may undermine competitiveness in certain sectors/sub-sectors. Delivering a robust successor agreement to Kyoto is therefore key.

Trajectory D: This trajectory infers a substantial level of industry closure leading to greater imports and therefore a relocation of carbon emissions. From a consumption perspective this may not necessarily reduce the UK's carbon emissions.

Other Comments: Whilst trajectory D leads to reduced greenhouse emissions in the UK it will necessarily result in carbon emissions being produced elsewhere. Given that climate change is a global problem, one output from the model should be recognition of the level of emissions that will result elsewhere in the world from UK carbon leakage.

D. Space heating, hot water and cooling

Energy demand levels

Level 1: Insulation measures possible but not likely due to current penetration levels, which are driven by energy supplier obligations. This scenario also assumes that by 2050 all properties will have air conditioning whilst not insulating their property, which suggests a high energy cost to customers compared to today.

Level 2: In general the uptake of insulation measures feels too low. Would expect 100% penetration of cavity and loft insulation assuming current trend in policy.

Level 3: As noted for level 2.

Level 4: There is a question over the value of this scenario as 100% penetration of insulation of housing stock could be achieved in level 3, i.e. following the principle of 'hard but deliverable'.

Other Comments: Insulation measures present the best economic payback. This would suggest that penetration rates to be targeted as early as possible and to be completed by 2030.

Electrification of heating and cooling

Level 1: This is credible

Level 2: This is credible

Level 3: The 90% electrification scenario proposed here would have to assume that all existing housing stock is insulated and technology performance (COP) can supply to existing wet heating systems.

Level 4: Whilst this is a credible scenario it is likely to be cost prohibitive

Other Comments: All scenarios seem credible from a technical perspective. The technology pathways recognise the role of mCHP and district heating, which are an important part of the technology mix to 2050. We have the challenge of finding a lower carbon technology that can replace the individual heating boilers that exist in today's buildings. Micro-CHP fits this role and could decarbonise further if bio-gas is developed as a replacement for natural gas. Micro-CHP could also be a useful demand side management tool in a future where renewable electricity generation requires greater control over energy flow in the system. District heating is a core technology to develop a sustainable local community energy solution. Early take-up is more suited to new build property developments, however the expansion of these heating networks to existing and adjacent properties could provide a highly efficient heating solution. Again further opportunity to decarbonise exists if bio-gas is developed.

It is likely that a mixture of electric and non-electric heating solutions will be required and the payback period for these two main technology groups will be dependent on location and project specifics. The majority of heating systems in the UK are fuelled using natural gas. However there are a substantial (4 million) number of properties that are not on the gas grid and are either fuelled by electricity, coal or oil. Therefore more efficient electric heating solutions (heat pumps) are the solution for off-gas properties. The mix of electric and non-electric heating solutions is likely to change over the next 40 years. For example mCHP could be a transitional technology, which may be replaced by heat pump technology in say 20 years if the relative cost, performance and reliability of the heat pump is competitive. However we believe mCHP and heat pump technologies can co-exist in the future, the (bio-gas) mCHP could provide controllable local generation with the heat pump providing controllable power demand with heat storage.

From a distribution perspective we would also suggest that changes to the method by which DNO's are informed of heat pump installation would facilitate a reduction in their impact. At present the customer can in most cases "connect an inform" such that if the connection of the heat pump has undesirable effects on the local network then the DNO can only take action after the event. If this were to "inform and connect" then potential issues could be identified earlier in the process. Overcoming these issues could speed the role out of this technology at lowest cost to the consumer.

E. Agriculture and land use

Other Comments:

Whilst we would anticipate that the effort considered for this sector is scientifically achievable, we are unable to comment on the proposed levels.

F. Bioenergy and waste

Biomass

Trajectory A: Achievable

Trajectory B: This is possible but unlikely. Our Biomass team would expect that if food crops increase, there will be potential to use bi-products for bioenergy, either in the form of combustion technologies or biogas technologies.

Trajectory C: likely outcome out of the 4 scenarios as there is better symbiosis with food farming

Trajectory D: involves increasing bioenergy crops land use to 4.2 million hectares. The numbers itself is obviously quite large but we think the carbon change in terms of the land use (30% of existing grassland converted) would need further work to consider if this increases or decreases carbon emission.

Waste

Trajectory A: This scenario is possible but unlikely given the amount of PFI contracts being put in place at the moment. In addition we think that landfill space (and cost to landfill) will still play a significant role in reducing this disposal route in the future.

Trajectory B: We would regard this trajectory as a more probable scenario and more in line with current policies to reduce landfill and increase recycling.

Trajectory C: We do not believe that this credible at present, especially with regard to 60% recycling by 2020.

Trajectory D: As above for trajectory C.

Other Comments: No further comments.

Algae

Level 1: We would consider this to be the most likely scenario.

Level 2: This would require government drivers in terms of an energy crop status with grants for uptake etc plus further incentives for bioenergy technologies (probably AD or something which could deal with moisture and high chlorine levels). The higher the incentives, the more development is required in this area. The Crown Estate would also need to issue licences for area use.

Level 3: As for Level 2 above.

Level 4: As for levels 2 & 3 above.

Other Comments: No further comments.

Imports

Level 1: This is unlikely to happen unless a very efficient way of using all other existing wastes/UK fuels/generation is developed and implemented

Level 2: We would regard this scenario as representing a possible future with the key risks being security of supply and sustainability.

Level 3: As above for Level 2.

Level 4: This would be a significant step change and we do not consider this to be a credible scenario.

Other Comments: No further comments.

G. Nuclear

Level 1: Achievable

Level 2: Based on the theoretical context of the Pathways analysis, levels 2 and 3 provide an intermediate ambition level which appears reasonable. However, by applying cost analysis and more appropriate market modelling the levels may vary from this.

Level 3: See above

Level 4: Whilst we would agree that this is technically possible we would regard this level of nuclear build as being highly stretching and therefore unlikely to come to fruition. At this level, we would also note the potential for system impacts in terms of nuclear inflexibility.

Other Comments: The alternative levels within this analysis are developed on the basis of what is physically possible without consideration for cost, policy support, supply chains and other variables such as planning approval which would have complicated the modelling. In this context, the levels of ambition for Nuclear power seem to cover the range of what is technically feasible. Using the French nuclear build programme in the 1970s and 1980s as a reference point is a reasonable approach.

In reality the actual nuclear build rate in the future will be driven by more than just what is physically possible. The report mentions the need for Government policy, clarity over planning, clarity over waste management, identification of suitable sites and availability of an appropriate skills base in the UK. In addition to the skills and capabilities of the supply chain, it is necessary to consider the fact that there are currently only two nuclear reactor vendors being considered under the licensing process in the UK. This will affect how much plant can reasonably be developed at one point in time, although one would anticipate more vendors being attracted as we move towards 2050.

H. Fossil fuel Carbon Capture and Storage

Level 1: Achievable

Level 2: Based on the theoretical context of the Pathways analysis, levels 2 and 3 provide an intermediate ambition level which appears reasonable. However, by applying cost analysis and more appropriate market modelling the levels may vary from this.

Level 3: See above.

Level 4: The 2009 Pöyry report *'Carbon Capture and Storage: Milestones to deliver large scale deployment by 2030 in the UK'* gives consideration to the practical issues facing industry, and their findings suggest that the Pathways level 4 trajectory of around 21GW by 2030 may be somewhat unrealistic.

Other Comments: The alternative levels within this analysis are developed on the basis of what is physically possible without consideration for cost, policy support, supply chains and other variables which would have complicated the modelling. In this context, the levels of ambition for fossil fuel CCS seem to cover the range of what is technically feasible in terms of build rates up to level 3.

Aside from the growth rate, consideration needs to be given to the resulting total capacity of fossil fuelled CCS which would be online as a result of levels 3 and 4. There may be issues around politically justifying such levels of fossil fuel use in the context of a low carbon economy.

As CCS is likely to have the highest short run cost of the low carbon generation options, it is likely that generation from CCS plants will have their running limited. Whilst the load factor used may take account of this, in many scenarios the load factor may still be lower than that which has been assumed.

I. Onshore wind

Level 1: The industry can deploy 0.5GW p.a. based on historical data and so this path to 2025 is certainly credible. It is suprising however that re-powering does not seem to occur within this scenario. It is also worth noting that 0.94GW installed by 2020 would mean that the UK would fail to deliver on the 2020 targets. DECC's previous assumption in the scenario submitted to the EU had been 14-15GW by 2020.

Level 2: Deploying 1GW p.a. every year is above our historical target, but with some effort, this could be realised, given that other countries have been able to deliver this scale of deployment. This is the scenario that we would deem necessary to hit the 2020 targets from an onshore wind perspective. A maximum of 20GW on the system from onshore wind is at the top end of our current view.

Level 3: This is not considered to be a credible scenario. It would require increasing deployment rates with immediate effect by a factor of three.

Level 4: As above for level 3.

Other Comments: A load factor of 30% is too high and we would recommend amending this to 28%.

J. Offshore wind

Level 1: The industry can deploy 0.5GW p.a. based on historical data and so the path to 2025 is credible. The level of ambition is insufficient to deliver the 2020 targets. If level 1 onshore is added to these figures the total wind capacity is less than 16GW. This would be 11GW short of the 27GW required to meet the 2020 target.

Level 2: This scenario requires a significant ramp up in deployment rates to over 1GW p.a. for the first half of this decade followed by something closer to 2GW p.a. during the latter half of the decade. With new factories promised in the UK there is the potential to achieve this ambition, but it will require an increase of capacity from the whole supply chain and ensure that there is an appropriately skilled workforce sufficient to deliver three to four projects on an annual basis. The UK Government suggests that 27GW of wind could be installed by 2020. Assuming that 14.4GW of onshore wind can be delivered by this date, a slightly lower deployment rate of 1.2GW p.a. for the decade would suffice. In the long run it is feasible that 60GW could be installed, effectively all of Round 1, 2 and 3.

Level 3: The deployment rates being assumed between 2015 and 2020 of 3.5GW p.a. is not credible. Such rates are assumed to increase further to over 4GW from 2020 and 5GW from 2025. We believe that these numbers are far too aggressive. Finally, this scenario also assumes that projects can be built in much deeper waters (>60m), with current technologies we are unable to assess this development as credible at this stage.

Level 4: As above for level 3.

Other Comments: A capacity factor of 35% is too low and we would recommend that this is increased to 40%.

K. Tidal Range

Level 1: We would not agree with this scenario. There is no reason why wave generation will be a success but tidal will fail on either technical or commercial grounds. There is an increasing level of convergence in the tidal technology arena and involvement of major industrials such as Alstom, Voith/Siemens, Rolls Royce, Alstom along with others is also encouraging. More than 500 MW of tidal leases have been awarded in the Round 1 process to date with a further 200MW lease being negotiated with the Crown Estate at present. We would therefore expect a similar delivery path to that which has been witnessed in the wave power scenario. Indeed if the major industrials aforementioned remain in the sector there is no reason why we would not expect tidal to achieve greater levels of generation than wave technology. As with most renewable and energy generation technologies the scale of any development has a significant impact on the economics. This is certainly the case for marine generation where scale is needed to start the industry and to socialise high vessel costs and offshore operations.

Level 2: Our comments for the remaining levels of ambition our similar for both tidal stream and wave. Please refer to section 'L' below.

Level 3: Please refer to section 'L' below.

Level 4: Please refer to section 'L' below.

Other Comments: Our view is that Tidal range could deliver 0.5GW by 2020. Capacity factor will be higher for tidal than wave, but real experience is limited to date. We would consider thee model's assumed capacity factor of 40% to be achievable in the medium term i.e. by 2015-2020, but in the shorter term a conservative figure of 35% could be used.

L. Wave energy

Level 1: This scenario assumes that wave does not have a long term future. We would strongly disagree with this view. Ideally Level 1 should reflect the Pentland Firth and Orkney Waters lease round (Round 1), which has awarded over 600MW of leases to wave projects. There are also other projects in operation at EMEC, Wavehub continues to make progress and other independent trials are in operation. Therefore we would expect wave to deliver around 0.5GW by 2020.

Level 2: If wave is to be the new offshore wind post 2020, the path being modelled here between 2020 and 2030 is not stretching enough. We would expect that it would be possible to assume a deployment rate of 300MW p.a. from 2020 to 2030 if the technology can be made commercially viable. Therefore c3.5GW could be installed by 2030. Beyond 2030 it is difficult to predict, but we have assumed that deployment rates fall as re-powering of existing sites begins. Therefore a net increase of c100MW p.a. might be expected.

Level 3: This could be delivered if one assumes that as more effort is required annual deployment post 2020 is increased to 500MW p.a. out to 2030. This would result in 5.5GW being installed by 2030. With re-powering of sites post 2030, this is then scaled back to a net increase of 200MW p.a. between 2030 and 2050.

Level 4: We consider this option to be far too optimistic on the growth potential post 2020. Deployment rates should probably be capped at around 700MW p.a. between 2020 and 2030, resulting in 7.5GW being installed at the end of this period. Beyond 2030 the net increase after re-powering could be set at 300MW p.a. but this would be extremely ambitious.

Other Comments: For wave generation we believe that a capacity factor of 25% is at the low end of the range and would suggest increasing this to 30%.

M. Microgeneration of electricity

Small Scale Wind

Level 1:	Would question the inclusion of this scenario, which assumes little to no penetration of small scale wind.
Level 2:	Would suggest that there is minimal contribution to generation volumes from domestic applications.
Level 3:	This is credible
Level 4:	Whilst this is credible we would question whether saturation point for technology penetration would be as early as 2020

Other Comments: The majority of small scale wind installations are likely to be in the SME and Business sectors. The scenarios assume a quick build rate to a saturation point in 2016, which does not seem credible – particularly when compared with the more conservative penetration rates of insulation. Technology costs are likely to reduce over time, which would suggest an increase in growth year on year in more likely.

Solar PV

Level 1:	Possible and main assumption would be there is no government incentive to stimulate uptake.
Level 2:	This is credible
Level 3:	This is credible and would suggest this is the upper bound of maximum potential
Level 4:	This scenario, whilst technically feasible is not credible from a cost perspective.

Other Comments: The solar PV market is global. Technology costs and performance are expected to reduce over time.

N. Geothermal electricity generation

Whilst we would anticipate that the range of effort here is scientifically achievable we are unable to provide detailed comment on the proposed levels.

O. Hydropower

Level 1: We believe that level 1 should perhaps also reflect scope for some moderate growth as a result of the incentives provided by both the FIT and through re-powering opportunities at existing sites.

Level 2: This is a credible path but it will require a few new larger schemes being identified, some of which may be pumped storage.

Level 3: This is achievable but would be a very stretching ambition which may prove impossible once environmental constraints are taken in to account.

Level 4: We believe that the post 2020 growth expected in this scenario is optimistic and may prove unachievable when additional constraints (currently outside of the remit of the model) are taken in to account.

Other Comments: A capacity factor of 38% for hydro is a credible assumption.

P. Electricity balancing

Level 1: This is credible

Level 2: This is a credible scenario

Level 3: Levels 3 and 4 for pump storage (7GW and 20GW compared with 3.5GW today) seem excessively optimistic. The capital and engineering investment required to develop the suggested pumped storage lagoons in the sea or estuary areas would be immense. The considerable environmental impact should also be recognised, particularly given the aim of this entire project is to reduce the impact of energy processes on the environment.

Level 4: As above.

Other Comments: Further areas for consideration include;

Flexibility designed into generating stations – assumption of 5% boostable capacity does not appear to be logical. This links back to one of the main flaws with the model in that load factors are an assumption rather than an output. These should vary in response to the market needs.

Interconnection – The changeable conditions across Europe are unpredictable and often events in one country may not be isolated. For example, a cold snap is likely to affect several countries at once, with increased demand for energy across multiple locations. It is not possible to assume that interconnectors can provide stable or reliable capacity in the event of a shock event.

Q. Negative emissions

Whilst we would anticipate that the range of effort here is scientifically achievable we are unable to provide detailed comment on the proposed levels.

R. Electricity imports

Level 1: Achievable

Level 2: For Level 2 it is unclear which specific projects would actually provide the 30TWh of import. Specifically it is unclear what incentive other countries would have to develop concentrated solar power plants and long-distance grid connections primarily for export to the UK, instead of using the capacity locally.

Level 3: This is a stretching ambition. However, whilst the trajectories for Levels 3 and 4 are ambitious, they do refer to projects in specific regions which do give them a level of credibility.

Level 4: As above for Level 3.

Other Comments: It is clear that the limiting factor for the success of these projects is the ability to develop the appropriate interconnectors to actually import this electricity. Without any detail on the cost of such an undertaking it is difficult to assess whether it would justify the energy benefit.

(c) 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?

We agree that this is an appropriate approach for sectors such as Agriculture and Waste and that this approach has been clearly explained to users.

3. Input assumptions and methodologies:
(a) For each sector, are the input assumptions and the methodologies applied to those input assumptions reasonable?

The model should adjust the operating of various technologies in response to balancing supply and demand for that particular scenario. Instead load factors have been assumed as a fixed input, which makes some of the results unrepresentative of the real world conditions. Whilst the majority of our comments on the input assumptions have been included in the sectoral analysis above we have a number of comments on the specific Pathway Modules within the Excel model, not all of which refer to a specific Sector in the report:

Hydrocarbon fuel power generation - Conventional thermal plant *(Coal, gas, and oil-fired; non-CCS)*

The running of conventional thermal plant in the model varies dependant on the levels of other technologies. We have used the Alpha pathway as a reference point.

- For oil, the closure rates and thermal efficiency assumptions seem reasonable.
- For coal, the closure rates and thermal efficiency assumptions seem reasonable. However the fixed load factor of 60% across the entire 40 years is not sustainable. For an Alpha

pathway world, we would expect the load factors to be in the region of 50-55% in 2025, reducing to a level of 30-40% by the 2030s. Over time the coal plant will become increasingly peaking, and so we would expect load factors to drop even further. The modelling should be improved to reflect this.

- For gas, the fixed load factor of 70% across the entire 40 years is not sustainable. For an Alpha pathway world, we would expect the load factors to be in the region of 18-25% in 2025, reducing to a level of 10-30% by the 2030s. Over time the gas plant will become increasingly peaking, and so we would expect load factors to drop even further. The modelling should be improved to reflect this.
- The assumed coal to gas production ratio of 0.86 to 1 is very prescriptive. Basing future assumptions on past data is not logical. Gas, coal and carbon markets are volatile and may change drastically over the course of 40 years.

Hydrocarbon fuel power generation - Combustion + CCS (Section H)

- The thermal efficiencies and own use requirements seem reasonable. The load factor of 80% appears to be based on a plant availability assumption of 90%.
- Coal CCS plant will run as part of an integrated market, and therefore it is not solely the plant availability which drives load factors. Based on our view of an Alpha pathway, we would expect Coal CCS load factors to be in the region of around 60-80% up to 2025. It would be then expected they reduce to nearer 45-60% by 2035 dependent on other technologies and demand conditions in the market.
- As gas with CCS was not included in the Pathways Calculator, comment cannot be made on the assumptions. If further analysis is undertaken, it is important to understand the market forces affecting gas versus coal.

Nuclear power generation (Section G)

The input assumptions and methodology appear reasonable for the nuclear modelling.

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

We are sceptical of these trajectories. Energy crops, dry and wet biomass will be used to make bioenergy more in line with where they are and what they are near. Trajectory A seems closest to reality but fuel and technology will be more closely linked to location with a view to keep local fuel/resource used locally wherever possible.

(c) Can the model's assumptions on wave resource be improved, for example regarding the length of wave farms, their distance from shore, the efficiency of devices, constraints from other ocean users, and other assumptions?

Yes, the assumptions can be improved. The 'theoretical maximum' approach taken to estimate maximum generation has attracted much discussion. It is a very high level estimate and makes broad assumptions, for example about the fraction of power absorbed, which are very hard to verify. Constraints from other uses, grid access, behaviour of arrays, etc don't play a part in this estimation; neither does the efficiency of the device (the capture width).

It would be extremely helpful to see the assumptions here corroborated against estimates based on numbers of devices deployed, capture width, percentage of sites suitable for development, wake effects etc. However this is not straightforward, and is the subject of much ongoing research and speculation.

Perhaps the most realistic parameter to consider in the short to medium term is the limit at which capacity can be deployed. Over the next 3-4 years the outcome from feasibility studies and actual data from Round One projects will mean that the assumptions currently used within the model can be improved. As our own projects develop we would be happy to share our data with DECC on a bilateral basis to ensure that the assumptions used within the Pathways model are reflecting reality.

(d) 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?

The report correctly acknowledges the level of uncertainty. It is unclear exactly what assumptions have been applied from the report text alone. We have provided comments on the pathways based on our views on the feasibility of build rates.

(e) 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?

We have no comments.

(f) 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?

We have no comments.

(g) Could the relative roles of coal and gas out to 2050 vary from the assumptions shown in this work, and if so, how?

Further detail and analysis on Combined Cycle Gas Turbines (CCGTs) with Carbon Capture and Storage (CCS) would be worthwhile. Whilst the report recognises that coal and gas could both have an application to CCS, for modelling simplicity only coal is used as it is acknowledged that early commercial CCS deployment is likely to be coal fired. However, the technology applied, and input fuel markets for coal and gas CCS have fundamental differences. For this reason, it would be useful to consider gas with CCS as a separate sector with its own trajectories.

It is worth recognising that a holistic approach needs to be taken when assessing future pathways. Low carbon technologies should be considered in the context of the overall energy industry rather than in isolation. The role of other technologies such as unabated fossil fuelled electricity (especially gas generation) needs to be acknowledged as part of the future low carbon energy solution.

Established and proven technologies will have a role in enabling security of supply over the coming years as significant coal capacity is taken offline sooner than emerging technologies can be deployed on a commercial scale. Intermittency of supply will also be a key challenge with the increase in variable capacity such as onshore and offshore wind.

Peaking plant such as CCGT will still be necessary to ensure security of supply in the future. The Pathways Calculator includes fossil fuelled electricity as an effective last resort capacity brought online after all other technologies. It is unclear whether the modelling sufficiently reflects the need to balance the market especially given with events which could exacerbate the intermittency issue, such as anticyclones, as well as changing demand patterns in part influenced by an increased level of electrification. The report should have acknowledged the role of unabated fossil fuels as a part of the existing balancing solution. Instead there is very little mention of such plant, and no visible consideration of the key role it may need to play in the future.

4. Common implications and uncertainties:
(a) 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.

Whilst pathway Zeta does contain some assumptions around low levels of energy efficiency we believe that there may be merit in providing some detailed assumptions around the level of consumer behaviour change expected out to 2050. Indeed, the extent to which consumers are convinced of the need for urgent action to tackle climate change will determine the social and political acceptability of delivering high levels of effort across a range of sectors.

5. Impact of pathways:
(a) What criteria should be taken into account in understanding the impact and relative attractiveness of pathways?

Along with ensuring that all successful pathways hit the UK Government's commitments both in terms of renewable and greenhouse gas targets it is essential that this is achieved in a manner which results in affordable and secure energy supplies. It is clear from the model that whilst numerous options for achieving the 2050 goal exist, a diversified energy supply is common to all successful pathways. We believe that such diversification is key providing sustainable energy for the UK over the coming decades.

Whilst a pathway may initially look attractive it is important to note that certain routes are mutually exclusive. This is not necessarily obvious when using the pathways calculator. The model does not recognise the incompatibility of many of the highest levels of effort. This means that under numerous scenarios, the level 4 assumptions are undeliverable. Our understanding was that the brief to those developing this level of effort (during workshops in 2008) was that level 4 represents an indication of what is achievable for a given sector if it was the only priority for the country. Given this caveat, the model should prevent users from choosing more than one supply side and one demand side level 4 technology.

Additionally the original consideration of level 4 effort was a statement of what was physically possible assuming that the UK commenced on the path of devoting the nation's resources to this technology immediately (i.e. 2008). As this was not the case and we are now nearly three years on, the model needs to recognise this delay to build plans.

6. Cost analysis:
(a) 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?

New build could have a simple capex associated with it which could be annulised to give a £/unit/year. Combined with opex costs and fuel costs (explicitly stated assumptions) this would produce an annual cost of the energy system for 2050 (or any other year). These could reasonably be compared. For this to work however, it is essential that the more fundamental matching of generation to demand is corrected first.

We would also suggest that there should be a consideration of the level of subsidy which may be required to deliver the higher levels of zero/low carbon technology penetration. This aspect is particularly relevant considering that the UK will be one of many European nations competing to secure access to a sufficient level of these technologies.

Finally, it is clear that the concept of affordability will to a large degree be dependant upon the outcome of the successor global climate regime to the Kyoto Protocol. A robust and globally binding deal will vastly reduce the potential for carbon leakage and would give investors the confidence to pursue a low carbon path at a faster rate.

7. Future improvements to model:
(a) Do you have any further suggestions for refining the 2050 Pathways Calculator?

There is no indication of cost. Whilst this is made clear at the start of the document it would not be difficult to include this vital information and make the model much more useable. There is no indication that the user may have built too much supply side plant. It would be beneficial and easy to add an indication of the electricity capacity margin. Taking these shortcomings together it is very easy to unwittingly compose scenarios that make no financial or engineering sense.

Methodology

The model only does simple energy accounting using assumed load factors to predict output of technology types starting with high merit plant and working down until demand is met. The merit order for existing unabated generation with assumed load factors seems to be;

1. Oil 6%
2. Coal 60%
3. Gas 70%

These load factors are unsustainable with significant intermittent generation on the system. Furthermore if gas is lower merit than coal why has it potentially got a higher load factor?

A more serious problem is that the model seems to abandon the fundamental principal that generation = demand + losses. Running the model with pathway Alpha, but varying wind development between the four levels illustrates this. If level 1 wind is chosen then unabated conventional generation is required in 2050. Going to level 2 adds 237TWh of wind generation replacing the 203 TWh of unabated fossil. No other technology changes its output so there is 34 TWh extra generation for the same demand. Adding more wind by going to levels 3 and 4 has no effect on other generators (such as nuclear or CCS) and so generation greatly exceeds demand. The following graph illustrates this:

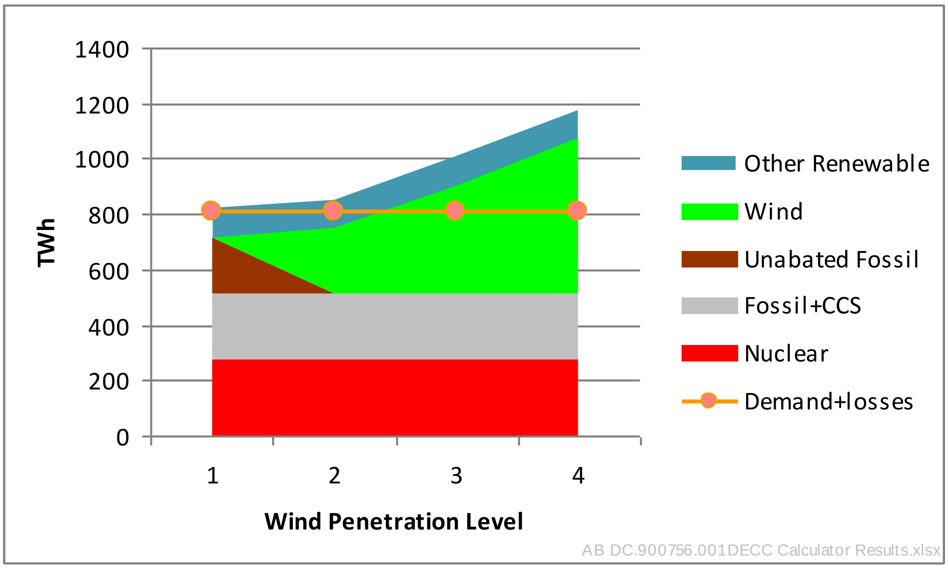

Fig 1: DECC Calculator Results for 2050, Pathway Alpha with varying wind penetration

It is not conceivable that nuclear and CCS in particular would not respond (within their flexibility limits) to increasing wind output by reducing their output when conflict arose.

A secondary effect is that the benefits of demand reductions are not felt by the system. In the following chart it can be seen that improving efficiency of lighting and appliances has no effect on generation and hence emissions. Note that the model shows no electricity exports, no reference is made to what happens to the excess.

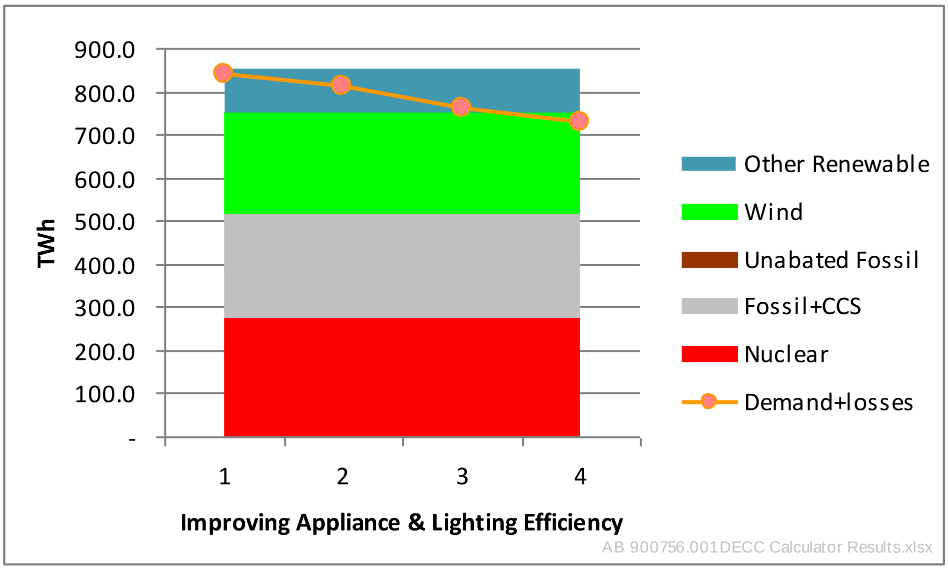

Fig 2: DECC Calculator Results for 2050, Pathway Alpha with varying electricity demand

To correct this, the model should divide the year into a number of time slices, each with a demand and a renewables availability (primarily a wind level), and stack the generation up in marginal cost order to meet the contestable demand. Load factors would then be an output and demand side measures would have an impact.

Clarity

Extensive use of Excel's reference functions, sometimes nested 3 deep, to laboriously construct cell references bit by bit makes it very difficult to follow the logic in the spreadsheet and trace numbers back to the original data.

Minor issues

Labels on "intermediate output" column D have exports and imports interchanged for electricity, coal and biomass.

Security of Supply Calculations

The output described as "5 still winter days" seems to bear little resemblance to any measure of security. For example pathway Alpha is described as needing 2GW of standby generation by 2050. Adding some extra offshore wind capacity by going to level 3 (but changing nothing else) increases standby requirements to 11GW. It makes no sense that adding generation (however intermittent) increases the requirement for plant to meet winter peak (when wind isn't blowing).

When rows in "Intermediate Output" are "unhidden" to see the data the Primary Supply and Demand graphics on Control sheet are spoilt.

(b) 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 the Pathways Calculator be improved such that the inherent degree of individual and local choice in a chosen pathway were clear?

The focus should be placed on getting the basics right. Extending to include regional factors may make the model overly complex.

Other Comments:

Finally we would like note that the development of the model depends very much on the intended purpose. If the model is designed purely to demonstrate an indicative level of effort required by a given sector in order to hit the 2050 target, it will require additional work especially with regard to balancing generation and demand. It will also need to take account of cost implications.

However, if the purpose of the model is to inform specific energy policy development going forward, we would be concerned. If the latter purpose is closer to the intention of government we would strongly recommend major changes especially in the areas of; balancing and security of supply implications, political and social barriers, improvements to load factor assumptions and of course robust assumptions around the financial implications for a given technology/pathway. We would also recommend that there is a process for regular updates to the model with robust governance arrangements.