MID WALES CONJOINED PUBLIC INQUIRY

ELECTRICITY ACT 1989

(SECTIONS 36, 37, 62(3) & SCHEDULE 8)

TOWN AND COUNTRY PLANNING ACT 1990 (SECTION 90)

APPLICATION BY LLANDINAM WINDFARM REPOWERING & EXTENSION, INCLUDING THE SP MANWEB 132Kv GRID CONNECTION

NOTE ON CARBON CALCULATIONS

A reply to the Alliance 2ND Proof of Evidence (POE) for the Closing Session (ALL-CLO-POE-02)

by

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Section 1. INTRODUCTION

QUALIFICATIONS

1.1. My name is Beverley Ann Walker and I am the Managing Director of BlueWind Consulting Ltd. I have previously provided written evidence to this Inquiry with regard to the topics of Hydrology, Hydrogeology and Eco-Hydrology for the Llandinam Extension and Repowering Project. My qualifications and experience are described in Section 1 of my Proof of Evidence (POE) for Session 1: SSA C.

1.2. Noted in Section 1 of my POE includes reference to my botanical qualifications and my 26 years experience as an EIA practitioner, particularly my previous consultancy roles which have included EIA project director, EIA project manager or EIA auditor /reviewer of over 25 onshore wind farm projects, predominantly in Scotland but also in Northern Ireland, Wales, England and the Republic of Ireland. Those full EIA's I have managed or directed have included supervision and checking of carbon budget/offset calculations for onshore wind farms using the methodologies developed by the Scottish Government. I am familiar with the early development of this approach from 2008, and the evolving iterations and applications of the methodologies currently adopted for such calculations.

KEY ISSUES

1.3. Matters to be addressed in this rebuttal/note relate to outstanding concerns from the Alliance in their 2nd POE for the Closing Session (ALL-CLO-POE-02) of the Mid Wales Conjoined Public Inquiry, with regard to carbon calculations. The Alliance presents the case that *'the carbon balance calculations provided by developers are now oversimplified and outdated, omitting a number of relevant factors that led to an underestimation of the carbon payback time of windfarms'*.

1.4. I do not agree that the current Carbon Calculator prepared for the Llandinam Development requires amendment. Importantly, changing technology and operating procedures mean that the past performance of turbines cannot be used to predict future performance.

1.5. Notwithstanding, and without prejudice to the above statement, adjustments made to the carbon calculator to address the Alliance concerns show that these make no significant difference to the carbon emissions or projected carbon payback time for the Llandinam Development.

SCOPE OF EVIDENCE

1.6. This note is confined to examining the current carbon calculations provided by the Llandinam Repowering and Extension Project, in light of the Alliance arguments, and includes any additional carbon considerations arising from the SP Manweb 132Kv Overhead Line Connection.

1.7. This note makes no comment on the implications of carbon calculations on the Planning Balance, which has been addressed by Peter Frampton in his Rebuttal Proof of Evidence (submitted 15 May 2014) To Dr John Constable on behalf of Alliance titled ‘Planning Balance’ (ALL-CLO-POE-01).

EXPERT STATEMENT

1.8. The evidence which I have prepared and provide for this Inquiry in this Rebuttal/Note is true and has been prepared and is given in accordance with professional standards, and I confirm that the opinions expressed are my true and professional opinions. Information relied upon in giving this evidence, which is contained within the SP Manweb application documents is considered to be true and accurate.

Section 2. REBUTTAL / NOTE

BACKGROUND

The Carbon Balance Calculator

2.1. Since 2003, the Scottish Government has published planning guidance[1] on how to calculate carbon emissions for onshore wind farms to explore whether a wind farm development is likely to represent a carbon saving or cost if it is built on peatland.

2.2. This guidance was refined in 2008[2] and a 'carbon assessment calculator' was developed to allow for consistent site specific input, which was subsequently adopted by the Scottish Government.

2.3. It is important to note that the Calculator is continuously updated and refined on the basis of ongoing research and user feedback. Version 2 of the Calculator[3] was published in 2011, along with detailed planning guidance on how the calculator should be used (CPL-CARB-01). Numerous updates of the calculator spreadsheet have since been published, the most recent being version 2.9.0 in April 22, 2014.

2.4. Although developed for Scottish environments[4], the Carbon Calculator is currently adopted throughout the UK and is recommended best practice for wind farm planning applications over peatland.

OBJECTION

2.5. The Alliance presents the case that 'the carbon balance calculations provided by developers are now oversimplified and outdated, omitting a number of relevant factors that led to an underestimation of the carbon payback time of windfarms'

2.6. Key factors which the Alliance suggest have been omitted or oversimplified include:

- The need to include the felling of in excess of 1,200 trees within the SP Manweb Overhead Line Grid Connection for the Llandinam development;
- Issues specifically related to input data for the Carbon Calculator, namely;
    - Wind turbine Component Replacement and Whole Life Projection (ie the effect of ageing);

[1] SNH Technical Guidance Note (2003) on Wind farms and Carbon Savings

[2] Nayak, D., Miller, D., Nolan, A., Smith, P., & Smith, J. (2008). Calculating carbon savings from wind farms on Scottish peat lands - A New Approach. For the Rural and Environment Research and Analysis Directorate of the Scottish Government, Science Policy and Co-ordination Division. http://www.scotland.gov.uk/Publications/2008/06/25114657/0

[3] J.U Smith et al (2011). Carbon Implications of Windfarms Located on Peatlands - Update Of The Scottish Government Carbon Calculator Tool. CR/2010/05

[4] In Scotland, the use of the calculator is mandatory for wind farms over peatland >50MW, and discretionary for windfarms <50M

- The makeup of the electricity fossil fuel and grid mix supply which is used in the calculations;
- The timescale of peatland restoration effects; and
- Issues related to access tracks, crane hard standings, turbine bases and other infrastructure;

2.7. The sections below discuss each of the Alliance points of concern.

RESPONSE

2.8. I do not agree that the current Carbon Calculator prepared for the Llandinam Development requires amendment. Importantly, any report/tool or counter opinion seeking to predict future performance based on UK operating history will be flawed for a number of reasons. Celtpower Ltd has advised that these can include the following:

- large variances occur between turbine types, mainly due to specific design/manufacturing factors of major components such as gearboxes.. This is particularly so as new technology such as the range of Direct Drive 'gearbox-less' turbines is rolled out, and as component manufacturing and testing improves;
- asset management strategies and supply chains have improved over time as the industry has matured, improving turbine availability. Inclusion of old turbines will not be representative

2.9. Therefore none of the turbines of the past can provide a basis on which to predict failure rates of current/future turbines

2.10. However in order to provide information to this Inquiry, and for illustrative purposes only, Appendix 1 presents a series of adjusted carbon balance calculations for comparison with those prepared in the 2013 SEI. These adjustments demonstrate that inclusion of the main concerns identified by the Alliance make little difference to the Carbon Calculator outcomes for the Llandinam project.

Tree felling over the SP Manweb Overhead Line Grid Connection

2.11. The Alliance suggests that over 1200 trees would be felled over the 35km length of the proposed overhead grid line which connects the Llandinam Development with the Welshpool substation, and that these should be included in the Llandinam development carbon balance calculations.

2.12. It is assumed, expressly for the purpose of responding to the Alliance, that the approximate number of 1200 as trees proposed to be removed is correct. CeltPower understands that this figure is not accepted by SP Manweb, and its use does not represent agreement on the part of CeltPower that it is in fact correct.

2.13. The accumulation of carbon by forest stands is often referred to as carbon sequestration. As noted by the Forestry Commission 2013 Information Note on Climate Change (CPL-CARB-02), the verb *to* *sequester* in legal terms, is defined as to seize temporary possession (of something), hence is considered to be a useful analogy when considering the carbon balance of trees. Carbon is temporarily stored by trees, then released. Burned or allowed to rot, a dead tree returns the carbon that it has fixed to the atmosphere, making a single tree's life effectively a carbon-neutral event.

2.14. Natural England (CPL-CARB-03) say *'Felling trees is not per se an important contributor to carbon emissions. Following felling there may be some increased loss of carbon from more rapid litter breakdown, but the carbon taken up by the felled trees remains within the timber until that is broken down (par 13.26)'.*

..and

2.15. *'Where regrowth or restocking does not take place, there is a potential net loss* ('carbon emission' – my words) of 50 t C/ha' (par 13:30). Whilst this 'carbon emission' is effectively a return to the atmosphere of the carbon that the tree has fixed over its lifetime, and would still occur in the future even if the current felling did not take place, it could be argued that this is a net 'emission' (average of 2 t C/ha/yr) with reference to the current timetable of climate change objectives and the 25 yr life of a wind farm.

2.16. Accordingly, loss of plantation forestry is included as a data input within the Carbon Calculator. Re-running the Llandinam Development Carbon Calculator with the inclusion of the Alliance tree fell numbers has been undertaken. Based on the assumptions described in Appendix A-2 (ie 1200 tree/ha), the increase of emissions is has been estimated by the calculator as 407 t CO2 eq (or 109 t C/ha)5. Re-running the calculator using this over-precautionary assumption still shows that this would result in an insignificant change in the carbon payback time for all scenarios (see Table A2 in Appendix A).

2.17. It is noted however the statement in paragraph 2.13 above also suggests that where replanting does take place, there is little net carbon loss (ie the carbon loss could be offset by new plantings).

2.18. Paragraph 4.4 of the updated 2013 ES states that SP Manweb has a statutory duty when delivering electricity infrastructure projects to ensure that it reinstates vegetation, trees, hedgerows, soils and other environmental resources which are unavoidably removed or displaced during construction operations. In addition, and in order to offset tree loss, SP Manweb propose to plant significantly more trees than the number being removed, with the objective of 2 to 1 replacement subject to landowner approval (Section 6.8.6).

2.19. At a worst case scenario therefore, the felling of 1200 trees could represent a potential 'premature' carbon emission of up to 50-100 t C/ha over a 10-25 years decomposition phase if the trees are left to naturally decompose. In a more realistic case, the loss of the felled trees over the long term would be carbon neutral, however any earlier carbon releases would be offset in the short term by the like for

[5] This suggests that the assumption of 1200 trees per hectare is double the realistic case.

like statutory replanting proposed by SP Manweb, with a net benefit arising from sequestration of carbon by any additional trees replanted under their 2 for 1 replanting policy.

Wind turbine Component Replacement and Whole Life Projection

2.20. The Alliance has argued that a life of 25 years for turbines as applied in the 'Carbon Calculator' is wrong. This is based on an analysis of data carried out by G. Hughes of the Renewable Energy Foundation (Alliance POE Reference 10) 6, which suggests that the load factor of turbines in the UK drops markedly over their lifetime, which in turn results in steady reduction in output over those years and a shortened economic lifetime. The Alliance argue that the Incorporation of this aging effect would significantly alter the carbon 'payback' time presented by the current Carbon Calculator.

2.21. The current Carbon Calculator assumes a lifetime of 25yrs for each turbine (which is the normal consent period applied for) and applies a steady state model with no (0%) decay in the load factor/output for each year over the 25 yrs.

2.22. Both the Scottish Government and DECC have considered the Hughes report, and both have rebutted its conclusions. The Scottish Government (CPL-CARB-04) expressed disappointment that the conclusions of the report were based on theoretical normalisations and not supported by empirical evidence. In May 2013 the Chief Scientific Advisor to the Department of Energy and Climate Change (DECC) (Professor MacKay) identified a significant flaw in the Hughes study, and concluded that 'most of the conclusions of the Renewable Energy Foundation study are believed to be spurious' (CPL-CARB-02). Professor MacKay found that while there was evidence for a reduction in the output of wind farms over time, he disputed it was by the amount claimed by Hughes. His own calculations suggested the load factor declines by roughly 2% per year, rather than the 5%, 6.5% or 12.8% per year asserted by the Renewable Energy Foundation.

2.23. In October 2013 the results of a formal academic and peer reviewed study by the Imperial College of London were published (CPL-CARB-06), which also examined the data collated by Hughes. This study by Staffell & Green concluded that load factors decline with age at a similar rate to other rotating machinery, and not at the rate claimed by Hughes. Based on their analysis of data, the performance of wind turbines in the UK were found on average, to lose 1.6 +/- 0.2% of their output per year, which is consistent with the conclusions of Professor MacKay. This decay reduced a typical wind farm's output by 12% over a twenty year lifetime..

2.24. I discussed this research with the Scottish Government Energy Division and the responsible agency for verifying the Carbon Calculator, namely the Scottish Environmental Protection Agency (SEPA. They advised me that the Carbon Calculator is reviewed on an ongoing basis as new research and evidence arises, and indicated that the outcomes of all relevant research (such as the McKay, and Staffell &

[6] Reference 10 of ALL-CLO-POE2. Hughes, G (2012) The Performance of Wind Farms in the United Kingdom and Denmark.

Green studies) would be considered for relevance during any future update.

2.25. Turbine capacity is dependent on a wide range of variables such as age of the technology, age of the machinery, wind speed and maintenance frequency, and therefore can vary from site to site. Although these above studies have not been approved for inclusion in the most recent version of the Carbon Calculator, and the data has not been verified by CPL, the 2013 Llandinam Development carbon assessment Calculator has been re-run for illustration purposes. Table A3 in Appendix A, shows that adjusting the calculator for a 2% loss of capacity (for example), would not have any effect on total carbon emissions, but that the payback periods for the expected scenarios using the grid-mix electricity supply could increase by 3 months. I do not consider this to be a significant effect.

Future Electricity fossil fuel and grid mix supply;

2.26. The Carbon Calculator was principally developed to estimate the net carbon balance achieved by the construction and operation of wind farms over deep undegraded peatland, which has its own conservation value. It calculates net carbon emissions, which is the data required by statutory authorities for reporting purposes. However carbon calculations are also used by the industry as a useful way to promote the carbon-'savings' and benefits achieved by the windfarm by discussing how it displaces electricity generated from coal-fired capacity and grid-mix. These savings are often expressed in terms of carbon 'pay back' time. 'Pay-back time' calculations are not necessarily linked to the Scottish Government Carbon Calculator, as they are routinely undertaken for wind farms which are not located on peatland (and hence which do not use the above calculator). Indeed, carbon emission 'life cycle assessments' and carbon 'pay back' time calculations are undertaken for all energy sources, including solar, nuclear and fossil fuel generators. There is no 'pay-back'time for fossil fuel generators.

2.27. As stated by the Alliance, the calculations in the current version of the 'Carbon Calculator' are based on the present fossil fuel and grid mix electricity supply. Clearly if the grid mix electricity supply were to change, the relative carbon offset and 'payback' time would also change. This is true for all energy sources which use this approach.

2.28. The Alliance makes reference to recent academic research (Alliance Reference 2) 7 undertaken by the authors of the Carbon Calculator, which models the potential grid mix into the future. In doing so, the authors advise that based on the current policies and rate of wind farm development, that over time the grid mix would have a higher proportion of energy from renewable sources, and hence there would be a reduced level of carbon 'offset'. They suggest that for wind farms constructed over undegraded peatlands, that 'the potential for C saving is very much reduced and (by 2040) most

[7] Smith J, Nayak D, Smith P; (2013). Windfarms on undegraded peatlands are unlikely to reduce future carbon emissions. Energy Policy66(2014)585–591

peatland sites will show no net C saving'. The Alliance argues that the current Carbon Calculator used for the Inquiry applications should adopt this predictive model, as this will reduce the perceived carbon benefits of the projects.

2.29. The Smith et al research paper is an academic modelling exercise based on theoretical assumptions and projections. As a forecasting exercise, it does not consider for example the introduction of fracking, carbon capture storage, or any other unknown or uncertain technology grid mix scenarios. The question is whether the Carbon Calculator or any other life cycle assessment should require developers and decision makers to consider a hypothetical grid mix and scenario based on only one scenario, which might or might not occur over the next 25 yrs time and towards the end of the current consenting lifecycle. It is unclear how introducing this level of uncertainty might be useful to the current decision making.

2.30. The Carbon Calculator includes the provision of an on-line link which is designed to allow future updates to the composition of the grid mix by reference to agreed UK statistical sources. Updates to the grid mix have already occurred over the life of the Calculator, including the most up to date calculations for the Llandinam Development. My discussions with Scottish Government and with SEPA suggest that there is no immediate desire to incorporate grid mix forecasting into the Calculator, but this does not mean that this research will not be considered in the future. However until such time as any new methodology is introduced, the baseline assumptions on grid mix will continue to be updated using emissions data which is contemporary with the consent application date. This is the current regulatory approach, and it would be inconsistent if the current applications were treated differently than other wind farm applications.

Timescale of peatland restoration effects

2.31. This objection is related to the wind farms in SSA B and not relevant to the Llandinam project.

Issues related to access tracks, crane hard standings, turbine bases and other infrastructure

2.32. This objection concerns potential underestimates of peat volumes carbon emission due to excavations, drainage lines, banking etc in and on deep peat during construction of wind farm infrastructure. The Alliance suggests these may not been entered into the Carbon Calculator.

2.33. In contrast, the input values in the Carbon Calculator for the Llandinam Development are highly precautionary. Several worst case assumptions have been made which have a cumulative effect on the calculator's outputs. As a consequence, in my opinion, the carbon payback times derived in the 2013 SEI have been significantly overestimated. For example:

1 It is assumed that the maximum turbine capacity will be 2.3 MW. A range of turbines might be used at Llandinam. The consent sought would allow up to a 3 MW capacity.

2 The Carbon Calculator was developed for use over deep peatland. It is not directly relevant to other environments[8]. The input data assumes the site is continuous deep acid bog or fenland. This is not actually the case at Llandinam.

3 Using the assumption that all of the site is located over continuous peatland, a 25m disturbance zone around ALL infrastructure was included as input data, notwithstanding the evidence presented in Appendix 2 of my POE for Session 1, which suggests that a realistic impact zone/drainage influence in peat (if it is present) is unlikely to be more than 10m (see REF).

4 The National Peat Map of Wales (CPL-HYD-002) shows that no areas of 'deep' peat have been mapped on the Llandinam site. Instead the site falls into the category of 'shallow peaty soils' (organo mineral soils) or 'soils with peaty pockets'. This means that the average peat depths over the site are overestimated, and the soils have lower than expected carbon content. This also means that most of the infrastructure does not impact peatlands, and could be excluded from the drainage impact area calculations described above.

5 Furthermore, and since the publication of the carbon calculations in the 2013 SEI, further work has occurred in association with NRW, to microsite the turbines and tracks away from almost all peat deposits on the site. This micrositing exercise is described in Inquiry document The Session 1 POE for David MacArthur, and is proposed as a condition. The revised area of peatland to be impacted by the Llandinam Development is calculated as 3.79ha of valley mire which is increased to 10.08ha if precautionary 25m drainage effects are included. .

2.34. For example, the data input into the Carbon Calculator assumes that the site is covered in a continuous layer of peat at an average depth of 1m. Using the Carbon Calculator the total area of peat loss is approximately 314 ha. By contrast, the real loss of peatland at Llandinam is 3.79 ha, which with an assumed drainage impact of 25m, increases the area to 10.08ha. This is a 10-fold difference.

[8] (CPL-CARB-01).

Section 3. CONCLUSIONS

3.1. The Scottish Government Carbon Calculator has been designed to identify the carbon cost of constructing wind farms over deep undegraded peatland. It is not intended for use in other environment.

3.2. The Carbon Calculator is continuously updated and refined on the basis of ongoing research and user consultation. Any new research material is reviewed and if found relevant, is added to the Calculator assumptions on a regular basis.

3.3. I do not agree that the current Carbon Calculator prepared for the Llandinam Development requires amendment. The studies used to support the Alliance objections are based on historic and discredited results for the impact of aging. Past performance of turbines cannot be used to predict future performance as it does not take into account improvements or changes in technology or operating procedures - .

3.4. The Llandinam site does not occur over areas of continuous deep peat, and the infrastructure avoids most areas of significant peat deposits. However, the data entered into the Carbon Calculator, including peat areas and potential drainage effects, is highly precautionary. This has resulted in a significant overestimate of potential carbon losses, not underestimates as suggested by the Alliance.

3.5. Re-running the carbon calculator for illustrative purposes demonstrates that the updates proposed by the Alliance will not make any significant difference to the carbon emissions or carbon 'pay-back' time estimated for the Llandinam Development.

3.6. Developers and decision makers are only able to follow published Guidance as it appears, and any unique application of unvalidated modelling to this Inquiry wind farms applications is not justified.

• REFERENCES

CPL-CARB-01 Scottish Government Planning Guidance: Wind Farm Developments on Peat Land fact sheet (First published June 13, 2011)

CPL-CARB-02 Forestry Commission (2013). Information Note: Forests, Carbon and Climate Change:the UK Contribution

CPL-CARB-03 Natural England (2009). Environmental impacts of land management (NERR030). Chapter 13. Tree Felling and Woodland Clearance

CPL-CARB-04 Scottish Government. Letter to John Constable of the Renewable Energy Foundation. Reference 2013/0011162. 30th May 2013.

CPL-CARB-05 David MacKay (2013). On the Performance of Wind Farms in the United Kingdom– Draft 6.0

CPL-CARB-06 Staffell.I & Green R (2013). How does wind farm performance decline with age? Renewable Energy 66 (2014) 775-786

APPENDIX A: Illustrative Revisions to the Carbon Calculator

Background - The Llandinam Development Carbon Calculator

1 The most recent carbon balance calculations for the Llandinam Development are provided in Chapter 14 of the 2013 SEI. This update reflects both the key changes to the Development (namely the removal of five turbines and a reduction in associated track length and crane hardstanding) as well as applying the update to the Calculator (Version 2 'Calculating carbon savings from wind farms on Scottish peat lands - a new approach' (version 2.7.0 October 2012).

2 The amended parameters used in the updated calculations (based on the revised Development) are summarised in Table 14-2 of the 2013 SEI, based on the expected minimum and maximum value. The output of the Calculator is provided in Table A1.

Table A1 Expected, Minimum and Maximum carbon emission values, as reported in the 2013 SEI

	Expt	*Min*	*Max*
Net emissions of carbon dioxide (t CO_2 $_{eq.}$)	**55702**	**55502**	**136911**
Carbon Payback Time			
…coal-fired electricity generation (years)	0.4	0.3	0.9
…grid-mix of electricity generation (years)	0.7	0.5	1.7
…fossil fuel - mix of electricity generation (years)	**0.6**	**0.4**	**1.4**

3 The following tables show the results of adjustments to the data input of the 2013 Carbon Calculator These adjustments are unvalidated[9] and are not intended to change any aspect of the Llandinam Development application.

Inclusion of Tree Felling

4 The version 2 updates to the calculator were undertaken to allow the inclusion of carbon emission losses from plantation forestry which are normally 'keyholed' for wind farm development. The Calculator only considers dense forestry planting for two species of conifers, and therefore any adaptation to the Calculator to consider broadleaf species which would be felled along the overhead route (which may have different carbon fixing rates to conifers depending on age class and species) increases the error margin. However, for the purposes of illustration, the following assumptions were made:

5 1200 trees represents 1ha at a density of 1000 trees/hectare (ie trees are assumed to be an average of 10metres apart);

6 The carbon fixation rate of the trees per hectare is equivalent to the figure provided by the Calculator for densely planted mature conifers

[9] The assumptions and conclusions of the Carbon Calculator require auditing/validation by SEPA before submission with a consent application. Adjustments to the calculator are only permitted for research purposes.

7 Table A3 provides the adjusted comparisons of emissions and payback time for the timber felling based on the above assumptions. The ageing effect has also been applied.

8 The results show that Inclusion of the overhead grid line tree felling has the effect of increasing the calculated carbon emission rates by from 0.2% (maximum scenario) to 0.6% (for the expected and minimum scenarios), with no discernable difference to payback time.

Table A2 Comparison of Expected, Minimum and Maximum carbon emission values with assumed felling

		Without Felling			*With Felling*		
		Exp	*Min*	*Max*	*Exp*	*Min*	*Max*
0% Decay (as per Table 1 above)	**Net emissions of carbon dioxide (t $CO_{2\,eq.}$)**	**55702**	**55502**	**136911**	**56087.1**	**55887**	**137318**
	Carbon Payback Time						
	…coal-fired electricity generation (years)	0.4	0.3	0.9	0.4	0.3	0.9
	…grid-mix of electricity generation (years)	0.7	0.5	1.7	0.7	0.5	1.7
	…fossil fuel - mix of electricity generation (years)	**0.6**	**0.4**	**1.4**	**0.6**	**0.4**	**1.4**

Aging effect

9 F or the sake of argument, the Mackay conclusion of an 2% reduction/year in load factor was applied to the input data for the Llandinam development Carbon Calculator, in order to compare the relative impact of an aging effect to the final carbon balance.

10 This resulted in an adjustment from an assumed 25% capacity, to an average capacity factor of 19.8% for a minimum scenario, and 27.75% for the maximum scenario. The adjusted data presented in Table A3 show that while the net carbon emissions have not changed, the payback time has increased marginally (by 2-3 months). This is not considered to be a significant effect.

Table A3 Comparison of Expected, Minimum and Maximum carbon emission values including felling (and adjusted for ageing effect (assumed 2%/yr decay rate)

		Without Felling			*With Felling*		
		Exp	*Min*	*Max*	*Exp*	*Min*	*Max*
0% Decay (as per Table 1 above)	**Net emissions of carbon dioxide (t $CO_{2\,eq.}$)**	**55702**	**55502**	**136911**	**56023**	**55822**	**137250**
	Carbon Payback Time						
	…coal-fired electricity generation (years)	0.4	0.3	0.9	0.4	0.3	0.9
	…grid-mix of electricity generation (years)	0.7	0.5	1.7	0.7	0.5	1.7
	…fossil fuel - mix of electricity generation (years)	**0.6**	**0.4**	**1.4**	**0.6**	**0.4**	**1.4**
2% Decay in capacity	**Net emissions of carbon dioxide (t $CO_{2\,eq.}$)**	**55702**	**55502**	**136911**	**56023**	**55822**	**137250**
	Carbon Payback Time						
	…coal-fired electricity generation (years)	0.5	0.3	1.1	0.5	0.3	1.1
	…grid-mix of electricity generation (years)	0.9	0.6	2.2	1.0	0.7	2.3
	…fossil fuel - mix of electricity generation (years)	**0.7**	**0.5**	**1.7**	**0.7**	**0.5**	**1.8**