Norwell Solar Farm Steering Group

Application by Elements Green Trent Limited for an Order Granting Development Consent for the Great North

Road Solar and Biodiversity Park (GNR Project)– project ref. EN010162

Unique Number -[redacted] (Our ref NSG/7)

Deadline 3. Response to Additional Information Provided by the Applicant.

Contents

Executive Summary

Following the recent additional design details released by the Applicant, a comparison is made between solar farm applications relying on the PVsyst software compared to those which adopt a load factor based on the published national annual load factors. The trend was that the software predictions generally forecast greater generation than the projects who adopted a factor based on the historical data.

The recent introduction of bifacial panels does justify some increase in output. Evidence from the UK and international studies suggests realistic gains of approximately 15% on grassland sites for the quoted panel design. Revised modelling by the Group therefore adopts a revised capacity factor of 12.07% (compared to the original of 10.5%), increasing lifetime solar generation but not to the extent claimed by the Applicant. The annual degradation rate also increases to 0.7%.

A central finding concerns the BESS. Scientific literature indicates that the proposed 85% depth of discharge will limit battery lifespan to approximately 11–12 years, necessitating a replacement rate of around 300% over the project lifetime. When realistic battery replacement, decommissioning emissions, and corrected embodied carbon factors are applied, total production emissions increase substantially. Similar concerns are raised regarding panel degradation and replacement assumptions, particularly for bifacial modules.

The three carbon-savings scenarios employed in the Group's earlier submissions are evaluated. Only the highly unlikely scenario—assuming static 2026 grid carbon intensity for 40 years—produces a marginal net emissions benefit. Under more realistic decarbonisation pathways, including DESNZ modelling, the project is shown to be a significant net contributor to greenhouse gas emissions.

The report concludes that the inclusion of the second BESS materially worsens the project’s climate impact. Removing the BESS and exporting solar generation directly to the grid reduces overall net emissions and represents the least environmentally harmful design option. Overall, the analysis finds that, as currently proposed, the project fails to achieve credible net greenhouse gas saving and possibly conflicts with national policy objectives to minimise lifecycle emissions

Content note: Parts of this executive summary were initially created using ChatGPT by the author who is a registered subscriber and an authorised user. Those parts were then edited manually by the author

1 Introduction

1.1 The purpose of this submission is to address new information supplied by the Applicant in their submission REP1-068, and during subsequent communications and a meeting with the Applicant's ES Consultant as part of the Statement of Common Ground (SoCG) process.

1.2 The Group accept that the net impact on the environment as result of the emissions associated with the construction,operation and decommissioning of this project are unlikely to be a single reason for a recommended refusal of the DCO. However, when examining the other adverse impacts against their compliance (or otherwise) with the National Planning Policy Statements, those impacts must be set against the background of what the effects of the project will be on climate change.

1.3 Liaison with the Applicant's consultant as part of the SoCG has been constructive and is ongoing and the Group are grateful for the co-operation received. There has been considerable agreement on many Greenhouse Gas (GHG) calculations. That said, differences on a small number of key issues remain. Principally, these revolve around projected avoided gas carbon emissions as a result of solar generation, and on the levels of replacement infrastructure during the project's lifespan. The Applicant has now submitted revised GHG calculations in REP2-075 (the new Appendix) and that document's contents will be also scrutinised here. The Group understand that a fourth version will be submitted before Deadline 3,

1.4 This report will contain hyperlinks but only to gov.uk sites. In line with the Inspectorate's Guidance on the use of Artificial Intelligence, the Group can confirm that none of this report (save as mentioned on the previous page) was created in the circumstances described in the Guidelines. As a general rule, AI has only been used as a passive search engine to discover published material which is then not altered in any way. Any website or citation will have a reference number immediately afterwards with the details at the end of this document on the URL and Citation page.

2 PVsyst versus Load Factors

2.1 The Applicant has at this late stage announced that their projected annual generation figures have been arrived at using the commercial software PVsyst (though it is not known which version). The Applicant's published generation formula (MWp x yield) is consistent with this software.

2.2 In the Terms and Conditions[1] for this software, the suppliers perhaps understandably state that the Company PV cannot be held responsible for the possible consequences of a difference in the production of a real system compared to a forecast of its software. It also states it will not be responsible should a developer modify the simulation report.

2.3 On 22nd December 2025, the Group requested that the Applicant publish the original PVsyst report (presumably dating back to 2023/2024). The Applicant has declined to do so, citing an unexplained commercial sensitivity. Some purported input figures have been supplied but not all the key variables.

2.4 Some solar farm developers have chosen to use this software whereas other have referenced UK load factors in order to calculate a project's generation capacity. Below is a table demonstrating recent solar farm projects and their effective load factors. This list was limited by the fact that not all applications included enough detail to enable inclusion:

Project Name	**PINs Reference**	**Export MW AC**	**Panel type**	**Source Document**	**Capacity Factor (CF) or PVsyst**	**Adopted or resultant capacity factor (%)**	**Annual generation MWh AC**
Mallard Pass (Rutland)	EN010127	350	Not selected	Page 10 APP-025	CF	10	350,000
East Yorkshire (Howden)	EN010143	480	Single axis (H) trackers	Page 6-41 APP-058	PVsyst	10	433,709
Dean Moor Solar Farm (Cumbria)	EN101155	150	Bi Facial fixed	Page 2 of APP-161	CF	10.2	134,028
Average Capacity Factor UK		2018-2023			CF	10.36 (see below)	
Helios Renewable Energy Project (North Yorks)	EN010140	190	Single axis (H) trackers	Page 1 of APP-162	CF	10.6	176,550
Heckington Fen Solar Park (North Kesteven)	EN010123	400	Bi Facial Fixed	Page 1 of APP-023	CF	11	385,704
Botley West (Oxfordshire)	EN010147	840	Fixed (Total DC capacity around 1,200 – 1,375 MWp)	Pages 17-18 of APP-215	CF	11.06	813,594

Project Name	Reference	Export MW AC	Panel type	Source Document	Capacity Factor (CF) or PVsyst	Adopted or resultant capacity factor (%)	Annual generation MWh AC
Sunnica (Cambs)	EN010106	630	Fixed with some Bi facial	Page 6-28 APP-38	PVsyst	12	643,361
Temple Oaks (Folkingham Lincs)	In scoping	240	Fixed	Page 1 Scoping report	PVsyst	14	294,000
Little Crow (Scunthorpe)	EN010101	100	Fixed	Appendix 4 of Deadline 4 Technical Guide	PVsyst	15	134,529
Great North Road (Newark)	EN010162	800	Bi Facial fixed		PVsyst	15.9	1,112,147
Byers Gill Solar (Darlington)	EN010139	180	Fixed	Page 19 and 20 of REP2-007	CF	16.7	263,872
Tillbridge (West Lindsay)	EN010142	500	Single axis (V) trackers	Pages 9 and 12 REP1-046	PVsyst	20	881,300

Table 1.

Table note: Since the Group's submission of Section 4 in REP1-102 , load factor data for 2024 has now been published at Dukes 3 by DESNZ. The Average UK factor above is the average for 2020-2024. Resultant Capacity Factors for PVsyst projects are calculated using the following formula:

$$\text{Capacity Factor} = \frac{\text{Annual MWh generation (according to the developer)}}{\text{MW Export AC} \times 365.25 \times 24}$$

2.5 Two of the above projects appear to be curious in the resultant or adopted factors. How the Darlington based Byers Gill project will achieve a capacity factor of 16.7% using fixed panels is not clear. Conversely, the East Yorkshire project using PVsyst and horizontal trackers, is projected to only achieve a factor of 10%. This seems on the low side.

2.6 Excluding these two projects, there is a clear trend. Not unsurprisingly perhaps, the developers who adopt a capacity factor, select a percentage in the region of the Dukes 3 DESNZ published national average factors. All the PVsyst projects predict factors substantially higher than the national average, irrespective of the type of panel used or the latitude.

2.7 There is no intention to get distracted here by scrutinising the potential gains one might expect by using trackers as opposed to fixed panels. However, the implications of the Applicant's late mention that bifacial panels are planned for the Great North Road project is worthy of scrutiny.

3 Bifacial Panels

3.1 The Group in its earlier submissions assumed fixed panels would be used as paragraph 43 of the Non Technical Summary APP-039 stated "*Fixed, south-facing solar panels were decided on...*" *.* At that stage bifacial panels are not mentioned but the Applicant's predicted annual solar generation has not changed since then. The Technical Appendix APP-285 assumes a conservative 10% capacity factor (page 3) and on page 14 a 650Wp panel. The first mention, as far as the Group can tell, of using 740Wp bifacial panels is on page 55 of the Written Summary of Oral Submissions REP1-068. As an aside, it is worth noting that the increased generation capacity of the bifacial panels would mean that one would need 14% less panels than if using 650Wp units. However, there has been no corresponding reduction in land grab.

3.2 The STC ratings for bifacial panels are based purely on the upper side of the panel. Any generation from the ground facing side is a bonus. Depending on the ground conditions and the consequential albedo effect, this choice of panel can affect an assumed capacity factor. With no earlier mention of bifacials, this Group adopted a capacity factor in its calculations of 10.5%. The Applicant's resultant capacity factor for the Great North Road project (15.8%) states that it will generate 50% more power than the average domestic solar farm and this seems to be as a result of using bifacial panels. This should now be reviewed.

3.3 The Sustainability Directory on its website[2] state that with less reflective surfaces such as grass, the gain might be in the 5-10% range. GlobalSpec*, a leading engineering resource in the USA, reports that US National Renewable Energy Laboratory study (2020) found that bifacial HJT panels could out perform monofacial panels by 21-24% but only in highly reflective environments. GlobalSpec report that dark surfaces could see minimal gains of 5-10%

3.4 In *"Predicting Yields of Bifacial PV Power Plants - What Accuracy is Possible?"* (2018) Chiodetti et al . Faunhofer[4] concluded that bifacials produce gains of 5-15%.

3.5 There are a range of studies examining this question. However, perhaps the most relevant is a real world assessment in *"A comparative study of bifacial versus monofacial PV systems at the UK's largest solar plant"* Badran and Dhimish (2024) Clean Energy Volume 8 Issues 4.Oxford University Press[5] Over 4 years,the comparative performance and degradation of monofacial and bifacial panels was measured on the same solar farm near York. It concluded that the bifacial panels outperformed by a factor 15.12-17.31%. However it also found that the bifacials had a marginally higher degradation rate of 1.17% per annum. One of the reasons this generation gain might be higher than other studies is shown in the image below:

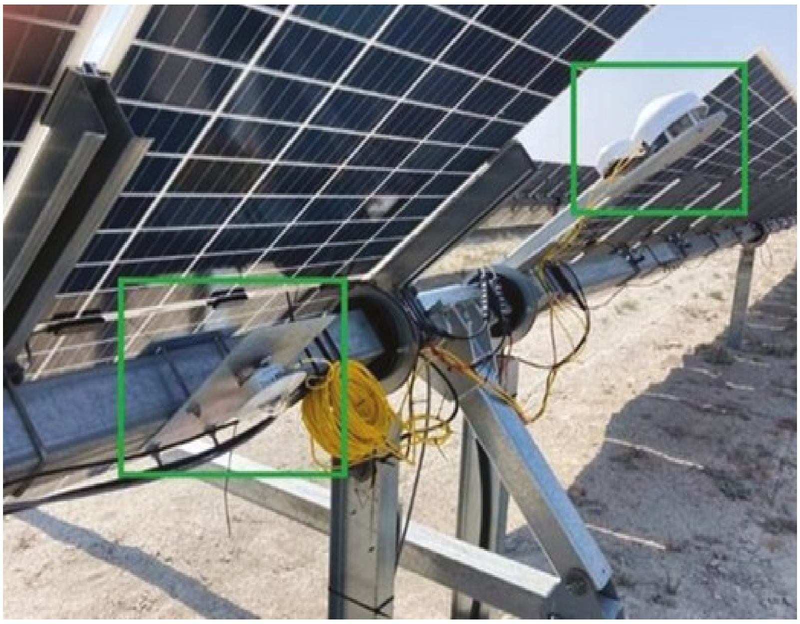

Plate 1

Courtesy Badran and Dhimish

3.6 It can be seen that the ground conditions for many of the bifacial modules have been cleared of grass, leaving a far more light reflective surface. The Great North Road ground surfaces will absorb more and reflect less energy as they will be grass pastures (required for the sheep). The Applicant in our Statement of Common Ground has quoted an acceptable albedo for the grass of 0.2. Given all these findings, it seems fair that the capacity factor of 10.5% previously adopted by the Group should be increased by 15% to 12.07%. The degradation rate will not be as high as in York due to less reflectivity but a generous 0.7% rate will be now adopted. These parameters will now be used to recalculate all predicted generation figures. It does alter the maximum theoretical annual generation :-

800MWac x 0.1207 x 365.25 x 24 = 846,445MWh
(Enough annual power for 248,954 homes)

4 Revised Savings in Emissions

4.1 Appendix A calculates the revised aggregate generation over the forty years. **This totals 29,594,028MWh.** Despite the higher degradation rate associated with the bifacials, this is over two million MWh higher than the Group's earlier calculations based on monofacial fixed panels.

4.2 Appendix B calculates the carbon avoidance resulting from solar generation from the panel after they have charged the BESS . **It shows these avoided emissions to be 454,445tCO_2**. In order for the 85% planned Depth of Discharge (DoD, as explained below) to be maintained, the same figures for charging the BESS are taken from the Applicant's table A15.1.19 in APP-285. The justification for the BESS is that it will have as much power as possible available to the grid for when it is most needed. In terms of the solar generated power, that will be the evening peak. That power can then be delivered in a controlled and timed manner. Reducing the amount the BESS is charged reduces the arguments in favour of having one.

4.3 In section 7 of our earlier report NSG/1 (pages 16-20, REP1-102), three scenarios were discussed resulting in three different carbon avoidance totals for energy supplied from the BESS. The first – the highly unlikely scenario, proposed by the Applicant, pegged the Evening Peak Carbon Intensity (Gas Peaker) at the 2026 figure for 40 years. As the same BESS charging figures are used in this report, then the same savings are repeated.

This would result in the below savings. There is no proposed change in the Applicant's 'Land Use Change' total.

Unlikely 2026 Pegged Emissions Scenario

Table 2

Development Phase	Total Avoided Emissions ($teCO_2e$)
Land Use Change	44,218
Solar PV Generation direct to Grid	454,445
BESS Discharge to Grid	3,246,690
Total	**3,745,353**

4.4 The second scenario proposed by the Group adopted reducing emissions savings over the 40 years, as the grid slowly decarbonised.

4.5 The third scenario employed the DESNZ grid decarbonisation predictions but inflated the average emission savings by a 140% to represent the higher gas emissions when using gas peaker generation. Appendix C shows the calculations for both scenarios based on the BESS discharge to grid annual figures adopted by the Applicant and this report. Again, it will be seen that the DESNZ predictions (even with a 140% uplift which some would think unlikely to be the case in decades to come) are more optimistic about decarbonisation compared to the Group's scenario. Below are the calculated emission savings for both scenarios:

Group's Scenario.

Table 3

Development Phase	Total Avoided Emissions ($teCO_2e$)
Land Use Change	44,218
Solar PV Generation direct to Grid	454,445
BESS Discharge to Grid	1,286,226
Total	**1,784,889**

DESNZ Modelling

Table 4

Development Phase	**Total Avoided Emissions ($teCO_2e$)**
Land Use Change	44,218
Solar PV Generation direct to Grid	454,445
BESS Discharge to Grid	479,058
Total	**977,721**

4.6 It will be seen there is a considerable difference between the three figures. Discounting the highly unlikely scenario (which cannot be "Rochdale compliant"), some might feel that the DESNZ modelling is perhaps optimistic. The likely savings are probably nearer to the Group's more pessimistic decarbonisation predictions.

5 Unreconciled Production Emissions.

5.1 PV Inverters.

5.1.1 Much progress has been made to resolve differences regarding the inverters, including agreeing a typical example for this infrastructure unit . There are still some unanswered questions about how many central inverters there will be but for the purposes of this exercise, there is agreement on the total weight to be used in transport calculations.

5.1.2 As part of the ongoing fact checking process, the Group has revisited the emissions factor employed by the Applicant. The Applicant relies upon the Rajput & Singh 2017 report[6] to source an emissions factor for the inverters, selecting 65.31kg/kw. The Applicant has been asked how this figure was arrived at as it does not appear in any context within that report. However, based on 198 inverters, average embodied carbon of 264tCO_2 per unit is broadly in line with what one might expect per inverter, so unless new information comes to light no change is suggested here.

5.2 Replacements.

5.2.1 Replacement panels

There is a far greater separation of views on what should be assessed as necessary infrastructure replacements, principally the panels and BESS cells.

5.2.2 Dealing first with the panels, the Applicant assumes a 10% replacement rate. The Outline Operation Environmental Management Plan REP1-035 (page 6) recognises that the panel surfaces may experience damage and that there will be inspections at least once a year to identify any damage. Such an event would lead to replacement as soon as possible.

5.2.3 During the Summary of Consultation Responses as presented on page 38 of Chapter 15 Climate Change REP2-030 , the Applicant states:

> *"It is made on the basis that the life expectancy is 40 years, but that not all panels will achieve that. There is a range of possible causes of a panel not lasting its expected lifetime, with physical damage being one of them."*

5.2.4 A comparison with other developers' expected panel lifespans and manufacturer projections has already been submitted (REP1-102 pages 14-15) and there is no intention to repeat them here. There is of course no empirical evidence that panels will last 40 years given how new the technology is. The Group have been unable to find any manufacturer who would guarantee performance beyond 30 years.

5.2.5 The Group agree with the Applicant that there are a number of reasons a panel will need replacing. The Group accept that if a panel still has structural integrity for the period 30-40years, it will still be capable of generation. However, as discussed earlier (in the Badran and Shimish study), bifacial panels such as the ones chosen here by the Applicant, degrade quicker than monofacial. Adopting the Badran and Shimish real world findings, one could expect these bifacial panels to have degraded by 35% by year 30. This is beyond what most in the industry appear to regard as the End of Life (EoL).

5.2.6 One excellent published academic review -"*Investigation of Degradation of Solar Photovoltaics: A Review of Aging Factors, Impacts, and Future Directions toward Sustainable Energy Management*" Rahman et al (2023) University of Bangladesh[7] – provides a comprehensive explanation as to how panels degrade and at what rate. The study includes the following imagery showing visible key ageing factors.

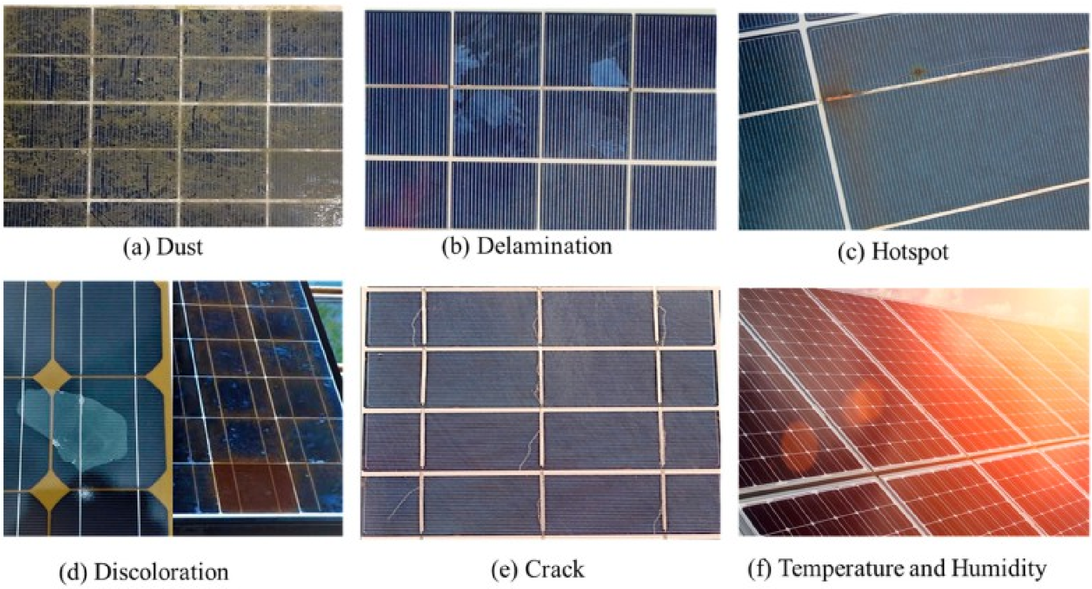

Plate 2

5.2.7 The findings of this study are very detailed and here is probably not the right place to explain them in any detail. Appendix D has extracts from the report though the full picture is only really seen when the report is read in full.

5.2.8 One of the more serious threats to panel lifespan in the UK are storms. Below are images of the damage to a recently commissioned solar farm on Anglesey following Storm Darragh:

(Image: No More Solar Farms Ynys Môn)

Plate 3

(Source Facebook)

Plate 4

(Image: No More Solar Farms Ynys Môn)

Plate 5

5.2.9 The Porth Wen Solar Farm had only been operational for a few months prior to this event. Anglesey is probably more likely to experience more storm severity than central Nottinghamshire.

However, the GNR Applicant's position is that such damage could never occur here in the next forty years, despite predicted increased wind speeds and storms that are more violent. That to some may appear to be a very optimistic approach.

5.2.10 The Applicant then takes the view that the anchoring of panels here would be guided by modelling on predicted forces from the wind to prevent such damage. This approach appears to be implying that the developers of Porth Wen decided to skip this procedure, despite being an experienced solar farm developer.

5.2.11 Given all the above, there is a strong case suggesting a mere 10% replacement rate for the panels over 40 years is a best case scenario and not realistic. It is the Group's position that a 50% rate in fact might be generous. However, that rate will be retained. This will lead to the following increases in the totals summarised in the latest Technical Appendix A15.

Panels Embodied Carbon	360,192tCO_2
Transport –	15,036tCO_2
Decommissioning	150tCO_2
Decommissioning transport	1125tCO_2

Total Additional Emissions – 376,503tCO_2

6 Depth of Discharge.

6.1 Paragraph 12 of the Outline Fire Safety Management Plan REP1-032 states:

> *"The battery cells have a design life of 25 years, and the DCO specifies an operational phase of 40 years"*

6.2 It is possible that this statement may give the wrong impression. The time it takes for a LfP battery to reach end of life (EoL) is very dependant on temperature and the average depth of discharge (DoD) each cycle. There are a number of published studies which demonstrate the greater the DoD, the fewer cycles a battery will last.

6.3 A helpful introductory article on this subject has been published by Mr Bob Wu entitled *"Depth of Discharge: How It Affects LiFePO4 Battery Life" 2025 Anern*[8] (battery manufacturers).

Wu quotes typical industry estimates which state that with average DoD of 80% a battery would be expected to last 4,000-6,000 cycles.

6.4 Included here also is a reference to *"A PSO-Optimized Fuzzy Logic Control-Based Charging Method for Individual Household Battery Storage Systems within a Community. Cheng et al (2018)* [9]. This study is useful as it goes into far more detail about the science leading to the degradation of these cells. It does of course concentrate on domestic batteries but the science is the same. It also provides a helpful graph as below:

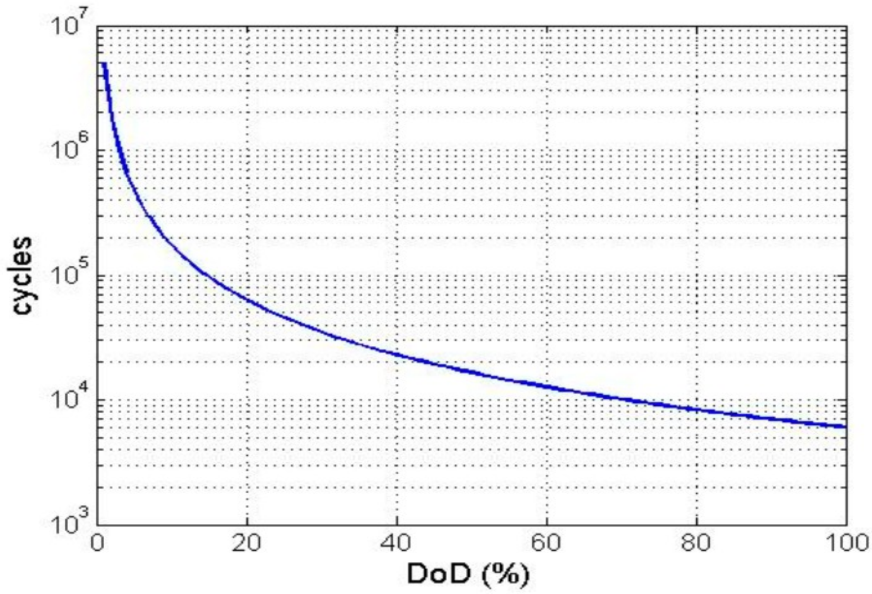

Figure 1

6.5 Whereas the above study principally looks at domestic cells, the following addresses the same issues but for utility scale energy storage systems. *"A Review on the Degradation Implementation for the Operation of Battery Energy Storage Systems"* Garcia-Miguel et al, 2022 University of Madrid.[10] This publication repeats much of the science but applies it to a BESS. It produces similar findings, represented by the graph below:

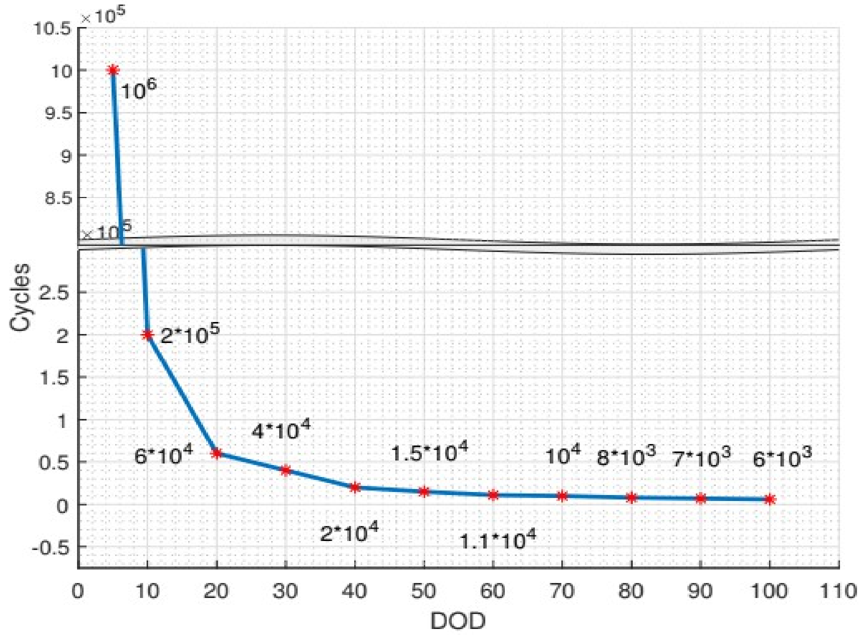

Figure 2

6.6 If need be, more studies and journals can be cited, all of which describe the reduction in achievable cycles brought about by increasing the DoD.

6.7 The Applicant has provided guidance on the intended DoD rates for this BESS in page 9 Statement of Common Ground with this Group REP2-108. That rate is 85%. When one compares that to the above two graphs, the first would suggest a lifespan of 8,500 cycles and the second 7,500. These two figures are actually higher than suggested by some other published papers and journals.

6.8 The Group's position has always been that the BESS will charge overnight from the grid. After all, the principal justification for this infrastructure is to balance out grid supply. Given that there may be a handful of days each when charging cannot occur (possibly because of maintenance or component replacement issues), it would be fair to assume at least that the grid charging will occur 355 nights a year.

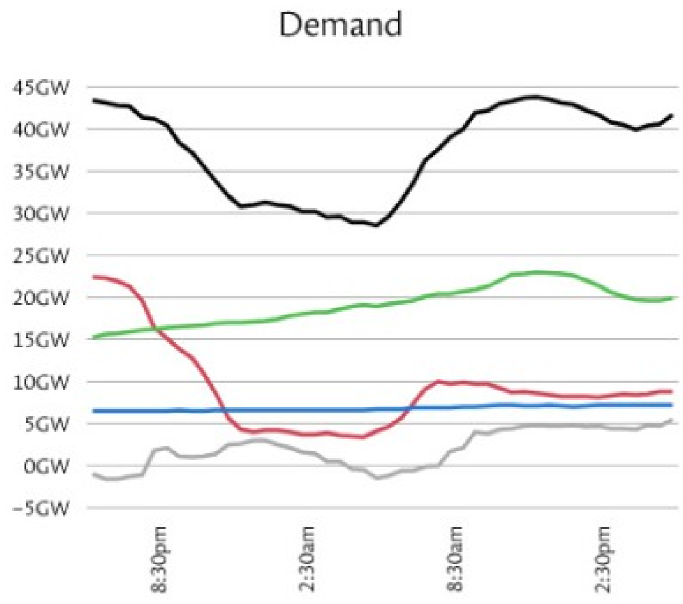

Figure 3

6.9 The above graphic, drawing on data from the National Grid showing demand overnight and into the day (30/01/26, from website grid.iamkate.com accessed 30/01/26), demonstrates the speed in the increase in demand for the morning peak and hence the need for increased generation and supply from storage.

6.10 As for calculating how many cycles are intended from solar charging, the Applicant has again assisted in that regard. In REP2-108, the Applicant has stated that for the greenhouse calculations, a depth of discharge/charge from solar would be 85%. 100% would be 880MWh so in the best year before any significant degradation in the BESS, a cycle would be 748MWh.

6.11 Table A15.1.19 in Technical Appendix REP2-075 (page 47) shows in year 1, 264,829MWh charged to the BESS from solar (and therefore 354 cycles of 748MWh), year 2 – 256,885MWh (343 cycles) and year 3-249,178 (333 cycles).

6.12 Thereafter, the amount charged annually to the BESS reduces, but due to degradation at the BESS, the total potential storage capacity also reduces so that 85% does not remain at 748MWh.

6.13 Combining the solar and grid powered cycles, a rough guide of annual aggregate cycles would be 680. Given that an 85% DoD would limit the total cycles to circa 8,000, that would mean the batteries would last 11-12 years. For the BESS to be still functioning up to year 40, that would require a replacement rate of 300%- the rate originally assumed by this Group.

6.14 Given the scientific data and published research, the Applicant's position that 50% of the cells will last 20-25 years is not tenable. To last that long the average DoD would have to be circa 58%. Such a DoD discharge would not be close to supplying the predicted annual MWh discharge to the grid. A 58% DoD would be 510MWh: 354 cycles at that rate would deliver 180,540MWh annually, as opposed to the Applicant's totals above (Y1-264,829MWh).

7 Battery Decommissioning Emissions.

7.1 A more worrying discrepancy with regard to the batteries has recently been discovered. The Applicant relies on page 2 of REP2-075 (and earlier versions) on the Rapier Report published on the website forbes.com[11] to calculate the embodied carbon for batteries. This is not challenged. Later in that report, Rapier indicates there will be a 4% loss between charge and discharge. This figure is also adopted in the Applicant's BESS calculations and the Group do not challenge its use either.

7.2 The Rapier report further addresses the end of life of Lfp batteries. It quantifies the decommissioning associated emissions to be 11kgCO2/kWh, drawing from the EU Product Environmental Footprint Category Rules. For some reason the Applicant did not adopt this figure on page 57 of REP2-075.

7.3 Instead the Applicant used a figure of 21.294kgCO_2/tonne, stating this is sourced from the Department for Business, Energy & Industrial Strategy, Greenhouse Gas Reporting: Conversion Factors, 2024. Checks have been made of that file (including using a ChatGPT search) to locate that factor. It is not anywhere in that database. This has now been agreed by the Applicant.

7.4 Using this figure on page 57 resulted in embodied decommissioning emissions of 407tCO_2. Adopting the Rapier report and using the EU Product Environmental Footprint Category Rules, then those emissions should be 24,200tCO_2. Following discussions with the Applicant, the correct factor has now been adopted by them and the figure below for the Applicant's production emissions has been amended accordingly on the assumption that the next Appendix A15 will have adopted this change.

The Applicant has stated that 21.294kgCO_2/tonne factor was sourced from the Byers Gill NSIP examination papers. This has been confirmed on the last page of Byers Gill Greenhouse Gas Assessment APP-123. It was not referenced and though clearly erroneous was not challenged in that examination. Alarm bells should have rung when in that document, the same decommissioning factor were used for steel and aggregate, and separately for batteries and plastic.

7.5 Below is a recalculation of the battery associated emissions given that it now seems inevitable that the replacement rate will have to be 300%. The initial construction and transport emissions remain the same.

Table 5

Phase	**Total tCO_2** (300% replacement)	**Applicant Total (tCO_2)**	**Net Increase over Applicant's figure (tCO_2)**
Replacement cells embodied carbon	939,840	469,920	469,920
Replacement Cells Transport	7,320	3,660	3,660
Decommissioning Embodied Carbon	38,720	24,200	14,520
Decommissioning Transport.	1,467	917	550
Total			**488,650**

7.6 Adding the new battery total to the revised panel total, **the production emissions must increase by 865,153tCO_2**

Since the publication of REP2-075 (which if one includes the PEIR version is the Applicant's third version of these calculations), the Applicant has agreed to amend another error on page 59. This has been done on the shared worksheets. The Applicant's total below includes this change even though at the time of writing, the latest version has yet to be submitted to the Authority. The total Emissions are now the Applicant's total -2,775,205 + 865,153 =**3,640,358tCO_2**

8 Misleading Attribution

8.1 Following the findings in 7.4 above, where the Applicant was sourcing the factor from the Byers Gill application papers, as opposed to the *"UK Government GHG Conversion Factors for Company Reporting" (2024, DESNZ),* but then stating the latter was the source, it was decided to further investigate other factors.

8.2 On page 49 of this Group's Climate Report REP1-102, it was pointed out that the tonne.km factor for shipping was wrong and this was accepted by the Applicant. The source was given as the above GHG Factors. However, on checking Byers Gill, the identical mistake was made on their page 4 of their earlier dated Greenhouse Gas Assessment APP-123. The chances of two independent analysts making this same mistake seems minute. The clear inference is that this was a copy paste from Byers Gill.

8.3 The Applicant throughout HGV transportation calculations has used a factor of 0.24kgCO_2 per tonne.km, giving the attribution as the GHG factors. This figure does not appear in the Freight HGV delivery factors in that database. This was discovered at an early stage. Their source was unclear but this Group did not seek to challenge it as it was in the ballpark of some of the database factors. The source now appears to be Byers Gill and that it is another copy paste from the same page as above.

8.4 In the Byers Gill Chapter 5 Climate Change APP-208, that Applicant does refer to the GHG Factors as a general source though in the Appendix, it is not clear which factors have been sourced from there.

8.5 The above points have been dealt with. The relevance of these copy pastes is that when this Applicant addresses the replacement rates for panels and batteries, these two are also copy pastes from Byers Gill. Had the GNR applicant investigated the lifespan scientific evidence, especially relating to the batteries, it is clear that the 150% rate for batteries had to be wrong. Just as if the Applicant had sourced the above factors from where they said they had, it would have been clear that the Byers Gill versions were wrong.

9 Net Emissions Savings

9.1 The following now represent the estimated impacts on greenhouse gasses from the construction, operation and decommissioning of this project.

Unlikely 2026 Pegged Emissions Scenario
Table 6

	tCO_2
Emission Savings	3,745,353
Production Emissions	3,640,358
Net Emission Savings	**104,995**

Group's Future Scenario
Table 7

Emission Savings	1,784,889
Production Emissions	3,640,358
Net Emission Savings	**-1,855,469**

DESNZ Modelling
Table 8

Emission Savings	977,721
Production Emissions	3,640,358
Net Emission Savings	**-2,662,637**

9.2 It can be seen that there is a marginal emissions benefit in the highly unlikely scenario but there are significant associated emissions predicted in the other two more likely models. Even if one disregarded the increased emissions associated with Group's increased replacement panels and cells, the project would still be a net contributor to increased greenhouse gasses.

10 Removal of the BESS

10.1 The Group have previously submitted arguments on what the impact would be of not including this second BESS in the design. Pages 16-17 of REP1-100 estimated the associated emissions for the BESS.

10.2 Since those reports, there have been significant design updates revealed and additional calculation errors uncovered. The net GHG savings in REP1-099 are now out of date.

10.3 Appendix E calculates the avoided emissions if all the panel generation left the intermediate substations and passed direct to the grid via the 400kv Staythorpe substation. That total is 693,333tCO_2. The revised BESS emission estimates are shown below:

Table 8

Material, activity or component	**tCO_2**
880,000kWh of Battery Cells embodied carbon (emissions factor sourced from Appendix APP-285 page 2. 300%replacement)	1,253,120
Cells HGV transport emissions	1,981
Cells sea journey emissions	7,780
Cells decommissioning	38,720
Cell decommissioning Transport	1,467
BESS Inverters (inc 150% replacement rate)	71,840
BESS Inverters transportation (sea from the Port of Shanghai and 2 HGV journeys)	2,902
BESS Inverter Steel Decommissioning	6
Inverter decommissioning transport	317
Estimated 2.5km of paladin security fencing around the BESS	163
Paint for fencing	34
palisade fencing around BESS substation	86
Sea Transport for that fencing	56
HGV transport for that fencing	25
Concrete (220 4MWh units x 15m²x 300mm plinths – 990m³ 2,475t) plus estimated 80 tonnes for substation foundations and concrete for fencing	267
Concrete Delivery	92
Concrete Decommissioning transport	29
Tarmac	226
Tarmac Delivery	104
Tarmac decommissioning (including transport)	56
Storage/Steel containers (Applicant estimates a maximum of 754 containers for the project. 2.2 tonnes each	4,495
Paint for containers	66
Total	**1,383,832**

Table Notes:The actual emissions total will be higher than the above total. Several constituent parts have not been included. These include some steel container transportation and decommissioning, loading/unloading of HGVs and ships, aggregate for tarmac road base, access tracks, geotextile membrane for tracks and substation (required under National Grid

specifications), the substation grid transformer and mineral oil, workforce related emissions, diesel to power generators and construction machinery, cabling, firefighting water storage, and fire suppression systems.

Reducing the total project emissions of 3,640,358tCO_2 by the BESS emissions aggregated in Table 8 reduces production emissions to 2,256,526tCO_2.

Net Project Emissions With No Second BESS

Table 9

	tCO_2
Emission Savings	692,333
Production Emissions	2,256,526
Net Emission Savings	**-1,564,193**

10.5 Though the project is still a net producer of greenhouse gasses, the design of this project without a second BESS is the least harmful to the environment. The BESS of course does not generate any renewable energy. Clearly, an assessment needs to be made as to whether this is relevant to :

> *"5.3.9 The Secretary of State should be content that the applicant has taken all reasonable steps to reduce the GHG emissions of the construction and decommissioning stage of the development."*
> Source:Overarching National Policy Statement for Energy (EN-1)

11 Conclusions.

11.1 This report provides updates on the climate change impact of this project due to more design detail now being available. It also incorporates the latest amendments to the Technical Appendix A15 which correct recently discovered errors, identified since the Group's initial analyses.

This has been achieved as a result of valuable and helpful liaison with the Applicant's ES Consultant.

11.2 Whilst there is a lack of evidence that the battery cells are capable of lasting 20 odd years with high a DoD , there is industry accepted scientific research showing that the planned 85% DoD will limit the battery lives to 11-12 years.

11.3 The replacement rate for panels and batteries remain significant areas of disagreement. However, there also remains another divergence of views, in particular how using bifacial panels on grass can increase the power generation by a factor of 50% compared to the national average for solar farm generation.

11.4 It is possible that the publication of the original PVsyst date stamped report may shed some light on this question but the Applicant is not making this available. That said, PVsyst theoretical reports recently have tended to be the higher in assumed resultant predicted capacity factors, compared to the real world measurement by DESNZ.

11.5 Forgetting the various highly unlikely scenarios explored by the Applicant, it seems inevitable that this project will be a significant net contributor to greenhouse gasses. The design which would cause the least harm is where the panels link directly to the Staythorpe BESS, currently under construction.

11.6 It is inevitable that constructing a generation station of any type will involve associated emissions. However, the objective must surely be to adopt a design which at least is neutral on net emissions, and if that is not possible, then to choose a design which is the least harmful to the environment.

Appendix A
Solar Generation with replacement panels

Year Number	Year	Panels last 29 years	30yrs	31yrs	32yrs	33yrs	40yrs	Total MWh AC
1	2026	42283	42283	42283	42283	42283	211417	422,834
2	2027	63171	63171	63171	63171	63171	315856	631,712
3	2028	83131	83131	83131	83131	83131	415655	831,311
4	2029	82549	82549	82549	82549	82549	412746	825,492
5	2030	81971	81971	81971	81971	81971	409857	819,713
6	2031	81398	81398	81398	81398	81398	406988	813,975
7	2032	80828	80828	80828	80828	80828	404139	808,277
8	2033	80262	80262	80262	80262	80262	401310	802,619
9	2034	79700	79700	79700	79700	79700	398501	797,001
10	2035	79142	79142	79142	79142	79142	395711	791,422
11	2036	78588	78588	78588	78588	78588	392941	785,882
12	2037	78038	78038	78038	78038	78038	390190	780,381
13	2038	77492	77492	77492	77492	77492	387459	774,918
14	2039	76949	76949	76949	76949	76949	384747	769,494
15	2040	76411	76411	76411	76411	76411	382054	764,107
16	2041	75876	75876	75876	75876	75876	379379	758,759
17	2042	75345	75345	75345	75345	75345	376724	753,447
18	2043	74817	74817	74817	74817	74817	374087	748,173
19	2044	74294	74294	74294	74294	74294	371468	742,936
20	2045	73774	73774	73774	73774	73774	368868	737,735
21	2046	73257	73257	73257	73257	73257	366286	732,571
22	2047	72744	72744	72744	72744	72744	363722	727,443
23	2048	72235	72235	72235	72235	72235	361176	722,351
24	2049	71729	71729	71729	71729	71729	358647	717,295
25	2050	71227	71227	71227	71227	71227	356137	712,274

Year Number	Year	Panels last 29 years	30yrs	31yrs	32yrs	33yrs	40yrs	Total MWh AC
26	2051	70,729	70,729	70,729	70,729	70,729	353,644	707,288
27	2052	70,234	70,234	70,234	70,234	70,234	351,168	702,337
28	2053	69,742	69,742	69,742	69,742	69,742	348,710	697,420
29	2054	69,254	69,254	69,254	69,254	69,254	346,269	692,538
30	2055	84,313	68,769	68,769	68,769	68,769	343,845	703,234
31	2056	83,723	84,313	68,288	68,288	68,288	341,438	714,337
32	2057	83,137	83,723	84,313	67,810	67,810	339,048	725,840
33	2058	82,555	83,137	83,723	84,313	67,335	336,675	737,736
34	2059	81,977	82,555	83,137	83,723	84,313	334,318	750,021
35	2060	81,403	81,977	82,555	83,137	83,723	331,978	744,771
36	2061	80,833	81,403	81,977	82,555	83,137	329,654	739,558
37	2062	80,267	80,833	81,403	81,977	82,555	327,347	734,381
38	2063	79,705	80,267	80,833	81,403	81,977	325,055	729,240
39	2064	79,147	79,705	80,267	80,833	81,403	322,780	724,136
40	2065	78,593	79,147	79,705	80,267	80,833	320,520	719,067
							Total	**29,594,028**

Table Notes

The Applicant's formula was based on its maximum DC MWp output (1120MWp) as its baseline to create its most productive annual MWh theoretical year before degradation. The above figures have as their baseline the equivalent real world best year without degradation as 846,445MWh AC based on an maximum 800MW AC generation capacity.The Applicants ratio of charging the . Columns 3-7 above all relate to 10% of the full array and represent replacements.

With year 3 being the most productive year, what might be expected is that that year would produce the 846,445MWh maximum as opposed to 831,331MWh as in the above table. However, just as the Applicant has done, the year 3 figure takes account of the 0.07% per annum degradation in the panels installed in the first 2 years.

The totals in this calculation do not take into account the Marginal carbon Intensity (kgCO2e/kWh) which will be applied in Appendix B. Save for the years in which panels are replaced, this table replicates the 0.7% panel degradation per annum assumed by the Applicant. All figures are in MWh AC.

Appendix B

Carbon Avoidance: Panels (with BESS charging)

Year Number	Year	Marginal carbon Intensity kgCO2e/kWh	Annual Energy Production (Mwh) AC	Charged to BESS (MwhAC)	Solar Energy to Grid (Mwh) AC	Carbon Avoidance (tonnes CO2e)
1	2026	0.174	422,834	264,829	158,005	27,493
2	2027	0.154	631,712	256,885	374,827	57,723
3	2028	0.133	831,311	249,178	582,133	77,424
4	2029	0.11	825,492	241,703	583,789	64,217
5	2030	0.085	819,713	234,452	585,261	49,747
6	2031	0.0652	813,975	227,418	586,557	38,244
7	2032	0.0501	808,277	220,595	587,682	29,443
8	2033	0.0384	802,619	213,978	588,641	22,604
9	2034	0.0296	797,001	207,558	589,443	17,448
10	2035	0.0226	791,422	264,829	526,593	11,901
11	2036	0.0174	785,882	256,885	528,997	9,205
12	2037	0.0133	780,381	249,178	531,203	7,065
13	2038	0.0102	774,918	241,703	533,215	5,439
14	2039	0.0079	769,494	234,452	535,042	4,227
15	2040	0.006	764,107	227,418	536,689	3,220
16	2041	0.0057	758,759	220,595	538,164	3,068
17	2042	0.0036	753,447	213,978	539,469	1,942
18	2043	0.0028	748,173	207,558	540,615	1,514
19	2044	0.002	742,936	201,332	541,604	1,083
20	2045	0.0013	737,735	264,829	472,906	615
21	2046	0.0013	732,571	256,885	475,686	618
22	2047	0.0013	727,443	249,178	478,265	622
23	2048	0.0014	722,351	241,703	480,648	673
24	2049	0.0013	717,295	234,452	482,843	628
25	2050	0.0023	712,274	227,418	484,856	1,115
26	2051	0.0023	707,288	220,595	486,693	1,119
27	2052	0.0023	702,337	213,978	488,359	1,123
28	2053	0.0023	697,420	207,558	489,862	1,127
29	2054	0.0023	692,538	201,332	491,206	1,130
30	2055	0.0023	703,234	264,829	438,405	1,008
31	2056	0.0023	714,337	256,885	457,452	1,052
32	2057	0.0023	725,840	249,178	476,662	1,096
33	2058	0.0023	737,736	241,703	496,033	1,141
34	2059	0.0023	750,021	234,452	515,569	1,186
35	2060	0.0023	744,771	227,418	517,353	1,190
36	2061	0.0023	739,558	220,595	518,963	1,194
37	2062	0.0023	734,381	213,978	520,403	1,197
38	2063	0.0023	729,240	207,558	521,682	1,200
39	2064	0.0023	724,136	201,332	522,804	1,202
40	2065	0.0023	719,067	195,292	523,775	1,205
					Total	**454,445**

Appendix C
BESS Emission Savings.

1. Group's Future Scenario

Year	Year	Evening Peak Carbon Intensity	Estimate charged to	Energy Discharged to Grid	Carbon Avoidance (tonnes)
Number		(Gas Peaker) (kg CO2e/kWh)	BESS (Mwh) AC	(MWh)	(tonnes CO2e)
1	2026	0.365	264,829	254,236	92,796
2	2027	0.365	256,885	246,610	90,013
3	2028	0.365	249,178	239,211	87,312
4	2029	0.365	241,703	232,035	84,693
5	2030	0.365	234,452	225,074	82,152
6	2031	0.365	227,418	218,321	79,687
7	2032	0.365	220,595	211,771	77,296
8	2033	0.365	213,978	205,419	74,978
9	2034	0.365	207,558	199,256	72,728
10	2035	0.365	264,829	254,236	92,796
11	2036	0.310	256,885	246,610	76,511
12	2037	0.264	249,178	239,211	63,083
13	2038	0.224	241,703	232,035	52,012
14	2039	0.191	234,452	225,074	42,884
15	2040	0.162	227,418	218,321	35,358
16	2041	0.138	220,595	211,771	29,152
17	2042	0.117	213,978	205,419	24,036
18	2043	0.099	207,558	199,256	19,818
19	2044	0.085	201,332	193,279	16,340
20	2045	0.072	264,829	254,236	18,269
21	2046	0.061	256,885	246,610	15,063
22	2047	0.052	249,178	239,211	12,419
23	2048	0.044	241,703	232,035	10,240
24	2049	0.038	234,452	225,074	8,443
25	2050	0.032	227,418	218,321	6,961
26	2051	0.027	220,595	211,771	5,739
27	2052	0.023	213,978	205,419	4,732
28	2053	0.020	207,558	199,256	3,902
29	2054	0.017	201,332	193,279	3,217
30	2055	0.014	264,829	254,236	3,597
31	2056	0	256,885	246,610	0
32	2057	0	249,178	239,211	0
33	2058	0	241,703	232,035	0
34	2059	0	234,452	225,074	0
35	2060	0	227,418	218,321	0
36	2061	0	220,595	211,771	0
37	2062	0	213,978	205,419	0
38	2063	0	207,558	199,256	0
39	2064	0	201,332	193,279	0
40	2065	0	195,292	187,480	0
				Total	**1,286,226**

2. DESNZ Modelling

Year Number	Year	Evening Peak Carbon Intensity (Gas Peaker) (kg CO2e/kWh)	Estimate charged to BESS (Mwh) AC	Energy Discharged to Grid (MWh)	Carbon Avoidance (tonnes) (tonnes CO2e)
1	2026	0.365	264,829	254,236	92,796
2	2027	0.323	256,885	246,610	79,666
3	2028	0.279	249,178	239,211	66,738
4	2029	0.231	241,703	232,035	53,541
5	2030	0.178	234,452	225,074	40,132
6	2031	0.137	227,418	218,321	29,860
7	2032	0.105	220,595	211,771	22,256
8	2033	0.081	213,978	205,419	16,547
9	2034	0.062	207,558	199,256	12,372
10	2035	0.047	264,829	254,236	12,053
11	2036	0.036	256,885	246,610	9,001
12	2037	0.028	249,178	239,211	6,674
13	2038	0.021	241,703	232,035	4,965
14	2039	0.017	234,452	225,074	3,730
15	2040	0.013	227,418	218,321	2,748
16	2041	0.012	220,595	211,771	2,532
17	2042	0.008	213,978	205,419	1,551
18	2043	0.006	207,558	199,256	1,170
19	2044	0.004	201,332	193,279	811
20	2045	0.003	264,829	254,236	693
21	2046	0.003	256,885	246,610	673
22	2047	0.003	249,178	239,211	652
23	2048	0.003	241,703	232,035	681
24	2049	0.003	234,452	225,074	614
25	2050	0.005	227,418	218,321	1,053
26	2051	0.005	220,595	211,771	1,022
27	2052	0.005	213,978	205,419	991
28	2053	0.005	207,558	199,256	961
29	2054	0.005	201,332	193,279	933
30	2055	0.005	264,829	254,236	1,227
31	2056	0.005	256,885	246,610	1,190
32	2057	0.005	249,178	239,211	1,154
33	2058	0.005	241,703	232,035	1,120
34	2059	0.005	234,452	225,074	1,086
35	2060	0.005	227,418	218,321	1,053
36	2061	0.005	220,595	211,771	1,022
37	2062	0.005	213,978	205,419	991
38	2063	0.005	207,558	199,256	961
39	2064	0.005	201,332	193,279	933
40	2065	0.005	195,292	187,480	905
				Total	**479,058**

Appendix D

Extracts from
"Investigation of Degradation of Solar Photovoltaics: A Review of Aging Factors, Impacts, and Future Directions toward Sustainable Energy Management"

Rahman et al (2023)

Manufacturers frequently offer warranties that guarantee a specific level of performance for a set period of time, sometimes 25 or 30 years, and that might provide insight into the predicted pace of degradation [27].

High temperature is a major cause of PV degradation. When a solar panel is exposed to high temperatures, it can cause several forms of damage that reduce the panel's efficiency and overall performance [28]. Some of the ways in which high temperatures can cause PV degradation include:

- Thermal stress: High temperatures can result in thermal stress inside the solar panel, which may cause the solar cells or other components to break or delaminate [29].
- Electrical resistance: The electrical resistance of the solar cells and interconnections increases with temperature, which can lower the efficiency of the panel [30].

Moisture can also be a cause of PV degradation. Moisture can enter the solar panel through various pathways, such as through cracks or defects in the panel's protective layers or through electrical contacts between cells [31]. Once inside the panel, moisture can cause several forms of damage that reduce the panel's efficiency and overall performance. Moisture can lead to PV degradation through the following mechanisms:

- Corrosion: Moisture can lead to the corrosion of the metal solar panel parts, including the frame and electrical connections. This may result in higher resistance and lower efficiency [32].
- Delamination: The materials used in solar panels, such as the encapsulant or back sheet, can delaminate as a result of moisture. This may cause the layers to separate, exposing the solar cells to moisture or other external elements [31].
- Electrical leakage: Moisture can also result in electrical leakage between solar panel cells or other components. This may result in decreased efficiency and a higher chance of electrical fires or failures [33].

PV deterioration can also be brought on by wind speed. Strong wind speeds can put the solar panel under mechanical stress, which can result in different types of damage that lower the panel's performance and efficiency [34]. The following are some ways that wind speed might lead to PV deterioration:

- Mechanical stress and vibration: Strong winds can bend or cause the solar panel to shake, which can put mechanical strain on the solar cells or other parts. This may cause the solar cells or other components to develop micro-cracks or delaminate, reducing the panel's power output [35].
- Structural damage: Damage to the solar panel's structure, such as the bending or deformation of the frame or supports, can also result from high wind speeds. This may result in the solar cells or other components being out of alignment, which will lower the panel's efficiency [36].

While it is often not as important a factor as temperature, moisture, or wind velocity, solar irradiance can also result in PV deterioration. The quantity of sunshine that strikes the solar panel is known as solar irradiance, and it has the potential to harm the panel in a number of ways that lower its overall performance and efficiency [37]. Solar irradiation can degrade PV in the following ways:

- Hotspots: When a portion of a solar cell is exposed to more sunlight than the rest of the cell, hotspots can form on the surface of the solar cell as a result of solar irradiance. This may result in localized cell damage and heating, which lowers the panel's overall power output. Several technologies, such as drone imaging, have been demonstrated to locate hotspots [38–40].
- Light-induced deterioration: When solar cells are exposed to sunlight for a lengthy period of time, they lose efficiency. Solar irradiance may also cause this type of deterioration. This can be influenced by the type of silicon used in the solar cells or by the presence of contaminants [41].

PV deterioration can also be brought on by the cell temperature. When exposed to sunlight, a solar cell transforms part of the energy into heat and some of it into electricity [42]. The solar cell's temperature may rise as a result of this heat, which may result in a number of types of damage that lower the cell's efficiency and overall performance.

- Light-induced deterioration: Long-term exposure to sunlight causes solar cells to lose efficiency. This kind of degradation might also be brought on by solar radiation. The kind of silicon used in the solar cells or the presence of impurities may have an impact on this [42].
- Thermal stress: Sudden temperature variations can put the solar cell under thermal stress, which can cause the micro-cracking or delamination of the cell or other components. Light- and elevated-temperature-induced degradation (LETID) can cause a decrease in the efficiency of solar cells, which leads to a decrease in the power output of the PV module. This decrease in power output reduces the overall energy production of the PV system and can result in lower financial returns. Additionally, LETID can also cause physical damage to the solar cells, such as cracking, delamination, and corrosion, which can lead to a shorter lifetime of the PV module. This might decrease the cell's power output and increase existing damage [29,43].

Citation: Rahman, T.; Mansur, A.A.;
Hossain Lipu, M.S.; Rahman, M.S.;
Ashique, R.H.; Houran, M.A.;
Elavarasan, R.M.; Hossain, E.
Investigation of Degradation of Solar Photovoltaics: A Review of Aging Factors, Impacts, and Future Directions toward Sustainable Energy Management. Energies 2023, 16, 3706.
https://doi.org/10.3390/en16093706

Appendix E

Panel Carbon Avoidance with No BESS

Year	Year	Marginal carbon	Annual	Carbon Avoidance
Number		Intensity kgCO2e/kWh	Production (Mwh)	(TCO2)
1	2026	0.174	422,834	73,573
2	2027	0.154	631,712	97,284
3	2028	0.133	831,311	110,564
4	2029	0.11	825,492	90,804
5	2030	0.085	819,713	69,676
6	2031	0.0652	813,975	53,071
7	2032	0.0501	808,277	40,495
8	2033	0.0384	802,619	30,821
9	2034	0.0296	797,001	23,591
10	2035	0.0226	791,422	17,886
11	2036	0.0174	785,882	13,674
12	2037	0.0133	780,381	10,379
13	2038	0.0102	774,918	7,904
14	2039	0.0079	769,494	6,079
15	2040	0.006	764,107	4,585
16	2041	0.0057	758,759	4,325
17	2042	0.0036	753,447	2,712
18	2043	0.0028	748,173	2,095
19	2044	0.002	742,936	1,486
20	2045	0.0013	737,735	959
21	2046	0.0013	732,571	952
22	2047	0.0013	727,443	946
23	2048	0.0014	722,351	1,011
24	2049	0.0013	717,295	932
25	2050	0.0023	712,274	1,638
26	2051	0.0023	707,288	1,627
27	2052	0.0023	702,337	1,615
28	2053	0.0023	697,420	1,604
29	2054	0.0023	692,538	1,593
30	2055	0.0023	703,234	1,617

contd

Year Number	Year	Marginal carbon Intensity kgCO2e/kWh	Annual Production (Mwh)	Carbon Avoidance (TCO2)
31	2056	0.0023	714,337	1,643
32	2057	0.0023	725,840	1,669
33	2058	0.0023	737,736	1,697
34	2059	0.0023	750,021	1,725
35	2060	0.0023	744,771	1,713
36	2061	0.0023	739,558	1,701
37	2062	0.0023	734,381	1,689
38	2063	0.0023	729,240	1,677
39	2064	0.0023	724,136	1,666
40	2065	0.0023	719,067	1,654
			Total	692,333

Table Notes: The Production figures are taken from Appendix A. The marginal carbon intensity figures are identical to those used by the Applicant in Table A15.1.19 on pages 39- 41 of the Technical Appendix A15.1 – APP-285.

References and URL's

Reference Number	Citation or URL
1	https://www.pvsyst.com/pdf/common/general-conditions-of-use-english.pdf (accessed 20/01/26)
2	https://energy.sustainability-directory.com/learn/what-is-the-difference-in-energy-gain-between-monofacial-and-bifacial-panels (accessed 19/01/26)
3	https://insights.globalspec.com/article/24288/bifacial-solar-panels-are-they-worth-the-hype (accessed 19/01/26)
4	https://publica.fraunhofer.de/entities/publication/c24e5d26-2224-432f-b505-1b90e4d5ae08 (accessed 19/01/26)
5	Ghadeer Badran, Mahmoud Dhimish, A comparative study of bifacial versus monofacial PV systems at the UK's largest solar plant, *Clean Energy*, Volume 8, Issue 4, August 2024, Pages 248–260, https://doi.org/10.1093/ce/zkae043
6	"Reduction in CO_2 Emission through Photovoltaic System: A Case Study": (2017) Saurabh Kumar Rajput1 and Omveer Singh2, IEEE Senior Member EEED, ABES Engineering College, Ghaziabad, india1 EED, School of Engineering, Gautam Buddha University, Greater Noida, India
7	Citation: Rahman, T.; Mansur, A.A.; Hossain Lipu, M.S.; Rahman, M.S.; Ashique, R.H.; Houran, M.A.; Elavarasan, R.M.; Hossain, E. Investigation of Degradation of Solar Photovoltaics: A Review of Aging Factors, Impacts, and Future Directions toward Sustainable Energy Management. Energies 2023, 16, 3706. https://doi.org/10.3390/en16093706____(accessed 22/01/26)
8	https://www.anernstore.com/blogs/diy-solar-guides/depth-of-discharge-lifepo4-battery-life (accessed 22/01/26)
9	Cheng, Sandy & Liu, Yi-Hua & Hesse, Holger & Naumann, Maik & Truong, Cong & Jossen, Andreas. (2018). A PSO-Optimized Fuzzy Logic Control-Based Charging Method for Individual Household Battery Storage Systems within a Community. Energies. 11. 469. 10.3390/en11020469.
10	Garcia-Miguel,Alonso-Martinez,Gomez, Plaza and Asensio. (2022) A Review on the Degradation Implementation for the Operation of Battery Energy Storage Systems. MDPI
11	https://www.forbes.com/sites/rrapier/2020/02/16/estimating-the-carbon-footprint-of-utility-scale-battery-storage/ Forbes (2020).(accessed 8/12/25)

Project Name	**PINs Reference**	**Export MW AC**	**Panel type**	**Source Document**	**Capacity Factor (CF) or PVsyst**	**Adopted or resultant capacity factor (%)**	**Annual generation MWh AC**
Mallard Pass (Rutland)	EN010127	350	Not selected	Page 10 APP-025	CF	10	350,000
East Yorkshire (Howden)	EN010143	480	Single axis (H) trackers	Page 6-41 APP-058	PVsyst	10	433,709
Dean Moor Solar Farm (Cumbria)	EN101155	150	Bi Facial fixed	Page 2 of APP-161	CF	10.2	134,028
Average Capacity Factor UK		2018-2023			CF	10.36 (see below)	
Helios Renewable Energy Project (North Yorks)	EN010140	190	Single axis (H) trackers	Page 1 of APP-162	CF	10.6	176,550
Heckington Fen Solar Park (North Kesteven)	EN010123	400	Bi Facial Fixed	Page 1 of APP-023	CF	11	385,704
Botley West (Oxfordshire)	EN010147	840	Fixed (Total DC capacity around 1,200 – 1,375 MWp)	Pages 17-18 of APP-215	CF	11.06	813,594

Project Name	Reference	Export MW AC	Panel type	Source Document	Capacity Factor (CF) or PVsyst	Adopted or resultant capacity factor (%)	Annual generation MWh AC
Sunnica (Cambs)	EN010106	630	Fixed with some Bi facial	Page 6-28 APP-38	PVsyst	12	643,361
Temple Oaks (Folkingham Lincs)	In scoping	240	Fixed	Page 1 Scoping report	PVsyst	14	294,000
Little Crow (Scunthorpe)	EN010101	100	Fixed	Appendix 4 of Deadline 4 Technical Guide	PVsyst	15	134,529
Great North Road (Newark)	EN010162	800	Bi Facial fixed		PVsyst	15.9	1,112,147
Byers Gill Solar (Darlington)	EN010139	180	Fixed	Page 19 and 20 of REP2-007	CF	16.7	263,872
Tillbridge (West Lindsay)	EN010142	500	Single axis (V) trackers	Pages 9 and 12 REP1-046	PVsyst	20	881,300

Table 1.
Table note: Since the Group's submission of Section 4 in REP1-102 , load factor data for 2024 has now been published at Dukes 3 by DESNZ. The Average UK factor above is the average for 2020-2024. Resultant Capacity Factors for PVsyst projects are calculated using the following formula:

$$\text{Capacity Factor} = \frac{\text{Annual MWh generation (according to the developer)}}{\text{MW Export AC} \times 365.25 \times 24}$$

2.5 Two of the above projects appear to be curious in the resultant or adopted factors. How the Darlington based Byers Gill project will achieve a capacity factor of 16.7% using fixed panels is not clear. Conversely, the East Yorkshire project using PVsyst and horizontal trackers, is projected to only achieve a factor of 10%. This seems on the low side.

2.6 Excluding these two projects, there is a clear trend. Not unsurprisingly perhaps, the developers who adopt a capacity factor, select a percentage in the region of the Dukes 3 DESNZ published national average factors. All the PVsyst projects predict factors substantially higher than the national average, irrespective of the type of panel used or the latitude.

2.7 There is no intention to get distracted here by scrutinising the potential gains one might expect by using trackers as opposed to fixed panels. However, the implications of the Applicant's late mention that bifacial panels are planned for the Great North Road project is worthy of scrutiny.

3 Bifacial Panels

3.1 The Group in its earlier submissions assumed fixed panels would be used as paragraph 43 of the Non Technical Summary APP-039 stated "*Fixed, south-facing solar panels were decided on...*" *.* At that stage bifacial panels are not mentioned but the Applicant's predicted annual solar generation has not changed since then. The Technical Appendix APP-285 assumes a conservative 10% capacity factor (page 3) and on page 14 a 650Wp panel. The first mention, as far as the Group can tell, of using 740Wp bifacial panels is on page 55 of the Written Summary of Oral Submissions REP1-068. As an aside, it is worth noting that the increased generation capacity of the bifacial panels would mean that one would need 14% less panels than if using 650Wp units. However, there has been no corresponding reduction in land grab.

3.2 The STC ratings for bifacial panels are based purely on the upper side of the panel. Any generation from the ground facing side is a bonus. Depending on the ground conditions and the consequential albedo effect, this choice of panel can affect an assumed capacity factor. With no earlier mention of bifacials, this Group adopted a capacity factor in its calculations of 10.5%. The Applicant's resultant capacity factor for the Great North Road project (15.8%) states that it will generate 50% more power than the average domestic solar farm and this seems to be as a result of using bifacial panels. This should now be reviewed.

3.3 The Sustainability Directory on its website[2] state that with less reflective surfaces such as grass, the gain might be in the 5-10% range. GlobalSpec[3], a leading engineering resource in the USA, reports that US National Renewable Energy Laboratory study (2020) found that bifacial HJT panels could out perform monofacial panels by 21-24% but only in highly reflective environments. GlobalSpec report that dark surfaces could see minimal gains of 5-10%

3.4 In *"Predicting Yields of Bifacial PV Power Plants - What Accuracy is Possible?"* (2018) Chiodetti et al . Faunhofer[4] concluded that bifacials produce gains of 5-15%.

3.5 There are a range of studies examining this question. However, perhaps the most relevant is a real world assessment in *"A comparative study of bifacial versus monofacial PV systems at the UK's largest solar plant"* Badran and Dhimish (2024) Clean Energy Volume 8 Issues 4.Oxford University Press[5] Over 4 years,the comparative performance and degradation of monofacial and bifacial panels was measured on the same solar farm near York. It concluded that the bifacial panels outperformed by a factor 15.12-17.31%. However it also found that the bifacials had a marginally higher degradation rate of 1.17% per annum. One of the reasons this generation gain might be higher than other studies is shown in the image below:

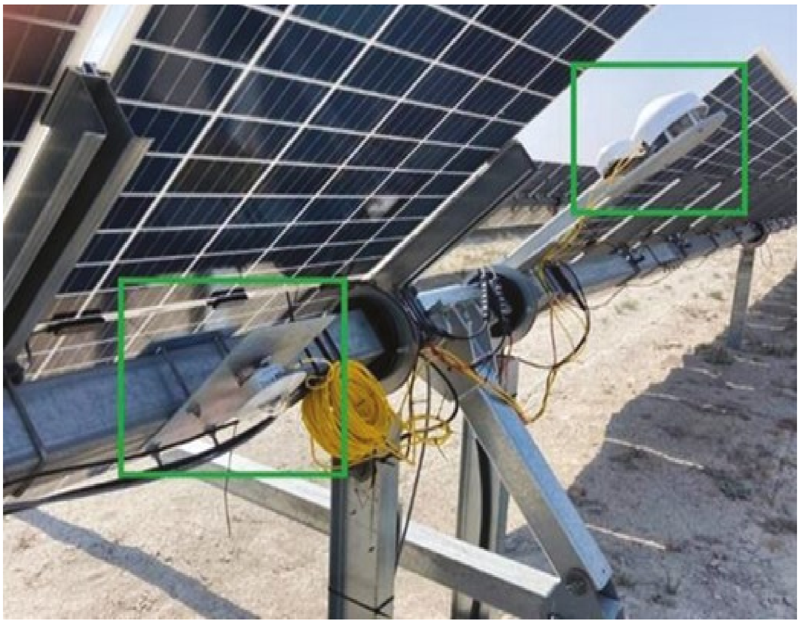

Plate 1

Courtesy Badran and Dhimish

3.6 It can be seen that the ground conditions for many of the bifacial modules have been cleared of grass, leaving a far more light reflective surface. The Great North Road ground surfaces will absorb more and reflect less energy as they will be grass pastures (required for the sheep). The Applicant in our Statement of Common Ground has quoted an acceptable albedo for the grass of 0.2. Given all these findings, it seems fair that the capacity factor of 10.5% previously adopted by the Group should be increased by 15% to 12.07%. The degradation rate will not be as high as in York due to less reflectivity but a generous 0.7% rate will be now adopted. These parameters will now be used to recalculate all predicted generation figures. It does alter the maximum theoretical annual generation :-

800MWac x 0.1207 x 365.25 x 24 = 846,445MWh
(Enough annual power for 248,954 homes)

4 Revised Savings in Emissions

4.1 Appendix A calculates the revised aggregate generation over the forty years. **This totals 29,594,028MWh.** Despite the higher degradation rate associated with the bifacials, this is over two million MWh higher than the Group's earlier calculations based on monofacial fixed panels.

4.2 Appendix B calculates the carbon avoidance resulting from solar generation from the panel after they have charged the BESS . **It shows these avoided emissions to be 454,445tCO_2**. In order for the 85% planned Depth of Discharge (DoD, as explained below) to be maintained, the same figures for charging the BESS are taken from the Applicant's table A15.1.19 in APP-285. The justification for the BESS is that it will have as much power as possible available to the grid for when it is most needed. In terms of the solar generated power, that will be the evening peak. That power can then be delivered in a controlled and timed manner. Reducing the amount the BESS is charged reduces the arguments in favour of having one.

4.3 In section 7 of our earlier report NSG/1 (pages 16-20, REP1-102), three scenarios were discussed resulting in three different carbon avoidance totals for energy supplied from the BESS. The first – the highly unlikely scenario, proposed by the Applicant, pegged the Evening Peak Carbon Intensity (Gas Peaker) at the 2026 figure for 40 years. As the same BESS charging figures are used in this report, then the same savings are repeated.

This would result in the below savings. There is no proposed change in the Applicant's 'Land Use Change' total.

Unlikely 2026 Pegged Emissions Scenario

Table 2

Development Phase	Total Avoided Emissions ($teCO_2e$)
Land Use Change	44,218
Solar PV Generation direct to Grid	454,445
BESS Discharge to Grid	3,246,690
Total	**3,745,353**

4.4 The second scenario proposed by the Group adopted reducing emissions savings over the 40 years, as the grid slowly decarbonised.

4.5 The third scenario employed the DESNZ grid decarbonisation predictions but inflated the average emission savings by a 140% to represent the higher gas emissions when using gas peaker generation. Appendix C shows the calculations for both scenarios based on the BESS discharge to grid annual figures adopted by the Applicant and this report. Again, it will be seen that the DESNZ predictions (even with a 140% uplift which some would think unlikely to be the case in decades to come) are more optimistic about decarbonisation compared to the Group's scenario. Below are the calculated emission savings for both scenarios:

Group's Scenario.

Table 3

Development Phase	Total Avoided Emissions ($teCO_2e$)
Land Use Change	44,218
Solar PV Generation direct to Grid	454,445
BESS Discharge to Grid	1,286,226
Total	**1,784,889**

DESNZ Modelling

Table 4

Development Phase	**Total Avoided Emissions ($teCO_2e$)**
Land Use Change	44,218
Solar PV Generation direct to Grid	454,445
BESS Discharge to Grid	479,058
Total	**977,721**

4.6 It will be seen there is a considerable difference between the three figures. Discounting the highly unlikely scenario (which cannot be "Rochdale compliant"), some might feel that the DESNZ modelling is perhaps optimistic. The likely savings are probably nearer to the Group's more pessimistic decarbonisation predictions.

5 Unreconciled Production Emissions.

5.1 PV Inverters.

5.1.1 Much progress has been made to resolve differences regarding the inverters, including agreeing a typical example for this infrastructure unit . There are still some unanswered questions about how many central inverters there will be but for the purposes of this exercise, there is agreement on the total weight to be used in transport calculations.

5.1.2 As part of the ongoing fact checking process, the Group has revisited the emissions factor employed by the Applicant. The Applicant relies upon the Rajput & Singh 2017 report[6] to source an emissions factor for the inverters, selecting 65.31kg/kw. The Applicant has been asked how this figure was arrived at as it does not appear in any context within that report. However, based on 198 inverters, average embodied carbon of 264tCO_2 per unit is broadly in line with what one might expect per inverter, so unless new information comes to light no change is suggested here.

5.2 Replacements.

5.2.1 Replacement panels

There is a far greater separation of views on what should be assessed as necessary infrastructure replacements, principally the panels and BESS cells.

5.2.2 Dealing first with the panels, the Applicant assumes a 10% replacement rate. The Outline Operation Environmental Management Plan REP1-035 (page 6) recognises that the panel surfaces may experience damage and that there will be inspections at least once a year to identify any damage. Such an event would lead to replacement as soon as possible.

5.2.3 During the Summary of Consultation Responses as presented on page 38 of Chapter 15 Climate Change REP2-030 , the Applicant states:

> *"It is made on the basis that the life expectancy is 40 years, but that not all panels will achieve that. There is a range of possible causes of a panel not lasting its expected lifetime, with physical damage being one of them."*

5.2.4 A comparison with other developers' expected panel lifespans and manufacturer projections has already been submitted (REP1-102 pages 14-15) and there is no intention to repeat them here. There is of course no empirical evidence that panels will last 40 years given how new the technology is. The Group have been unable to find any manufacturer who would guarantee performance beyond 30 years.

5.2.5 The Group agree with the Applicant that there are a number of reasons a panel will need replacing. The Group accept that if a panel still has structural integrity for the period 30-40years, it will still be capable of generation. However, as discussed earlier (in the Badran and Shimish study), bifacial panels such as the ones chosen here by the Applicant, degrade quicker than monofacial. Adopting the Badran and Shimish real world findings, one could expect these bifacial panels to have degraded by 35% by year 30. This is beyond what most in the industry appear to regard as the End of Life (EoL).

5.2.6 One excellent published academic review -"*Investigation of Degradation of Solar Photovoltaics: A Review of Aging Factors, Impacts, and Future Directions toward Sustainable Energy Management*" Rahman et al (2023) University of Bangladesh[7] – provides a comprehensive explanation as to how panels degrade and at what rate. The study includes the following imagery showing visible key ageing factors.

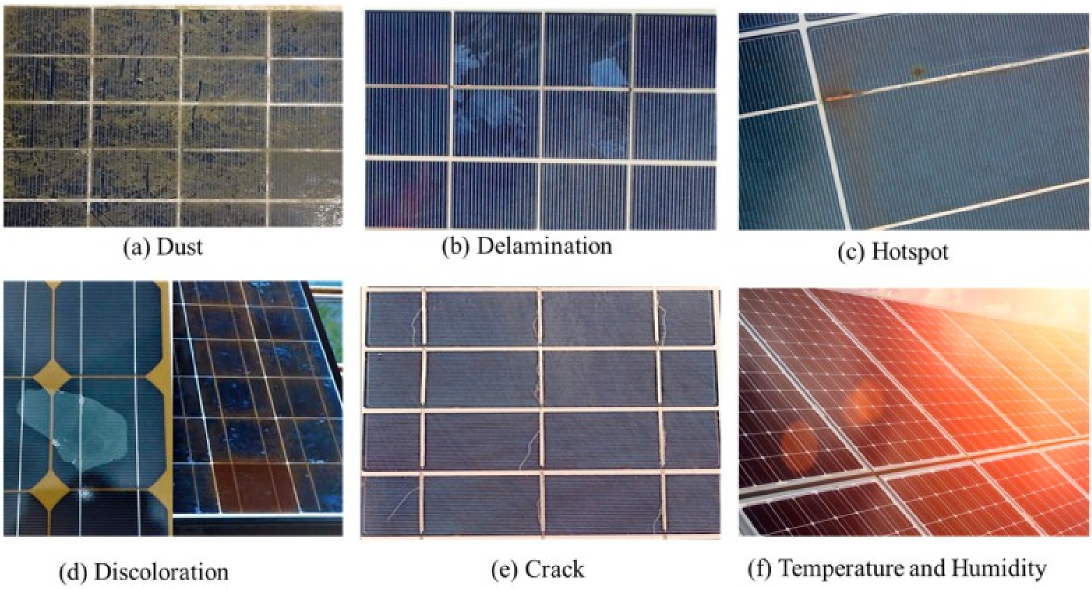

Plate 2

5.2.7 The findings of this study are very detailed and here is probably not the right place to explain them in any detail. Appendix D has extracts from the report though the full picture is only really seen when the report is read in full.

5.2.8 One of the more serious threats to panel lifespan in the UK are storms. Below are images of the damage to a recently commissioned solar farm on Anglesey following Storm Darragh:

(Image: No More Solar Farms Ynys Môn)

Plate 3


(Source Facebook)

Plate 4


(Image: No More Solar Farms Ynys Môn)

Plate 5

5.2.9 The Porth Wen Solar Farm had only been operational for a few months prior to this event. Anglesey is probably more likely to experience more storm severity than central Nottinghamshire.

However, the GNR Applicant's position is that such damage could never occur here in the next forty years, despite predicted increased wind speeds and storms that are more violent. That to some may appear to be a very optimistic approach.

5.2.10 The Applicant then takes the view that the anchoring of panels here would be guided by modelling on predicted forces from the wind to prevent such damage. This approach appears to be implying that the developers of Porth Wen decided to skip this procedure, despite being an experienced solar farm developer.

5.2.11 Given all the above, there is a strong case suggesting a mere 10% replacement rate for the panels over 40 years is a best case scenario and not realistic. It is the Group's position that a 50% rate in fact might be generous. However, that rate will be retained. This will lead to the following increases in the totals summarised in the latest Technical Appendix A15.

Panels Embodied Carbon	360,192tCO_2
Transport –	15,036tCO_2
Decommissioning	150tCO_2
Decommissioning transport	1125tCO_2

Total Additional Emissions – 376,503tCO_2

6 Depth of Discharge.

6.1 Paragraph 12 of the Outline Fire Safety Management Plan REP1-032 states:

> *"The battery cells have a design life of 25 years, and the DCO specifies an operational phase of 40 years"*

6.2 It is possible that this statement may give the wrong impression. The time it takes for a LfP battery to reach end of life (EoL) is very dependant on temperature and the average depth of discharge (DoD) each cycle. There are a number of published studies which demonstrate the greater the DoD, the fewer cycles a battery will last.

6.3 A helpful introductory article on this subject has been published by Mr Bob Wu entitled *"Depth of Discharge: How It Affects LiFePO4 Battery Life" 2025 Anern*[8] (battery manufacturers).

Wu quotes typical industry estimates which state that with average DoD of 80% a battery would be expected to last 4,000-6,000 cycles.

6.4 Included here also is a reference to *"A PSO-Optimized Fuzzy Logic Control-Based Charging Method for Individual Household Battery Storage Systems within a Community. Cheng et al (2018)*[9]**.**This study is useful as it goes into far more detail about the science leading to the degradation of these cells. It does of course concentrate on domestic batteries but the science is the same. It also provides a helpful graph as below:

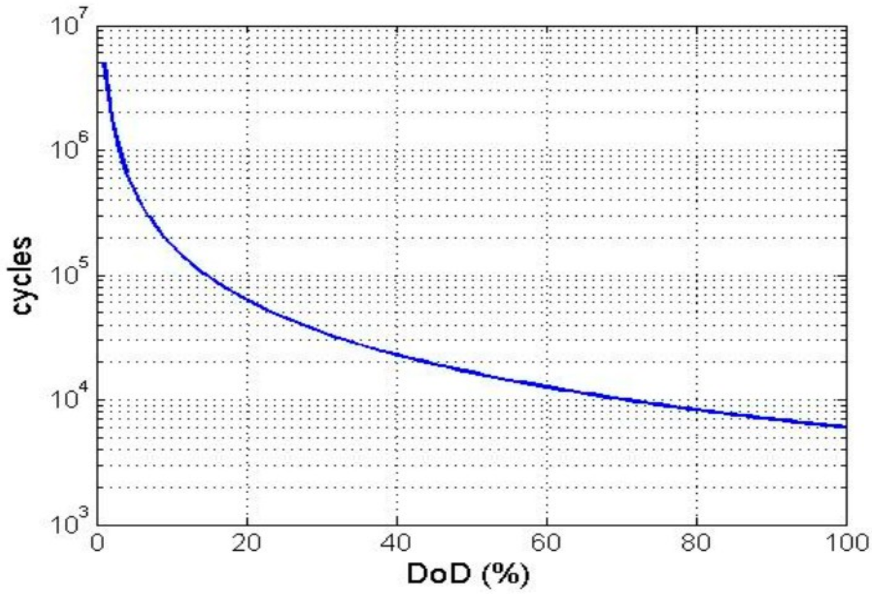

Figure 1

6.5 Whereas the above study principally looks at domestic cells, the following addresses the same issues but for utility scale energy storage systems. *"A Review on the Degradation Implementation for the Operation of Battery Energy Storage Systems"* Garcia-Miguel et al, 2022 University of Madrid.[10] This publication repeats much of the science but applies it to a BESS. It produces similar findings, represented by the graph below:

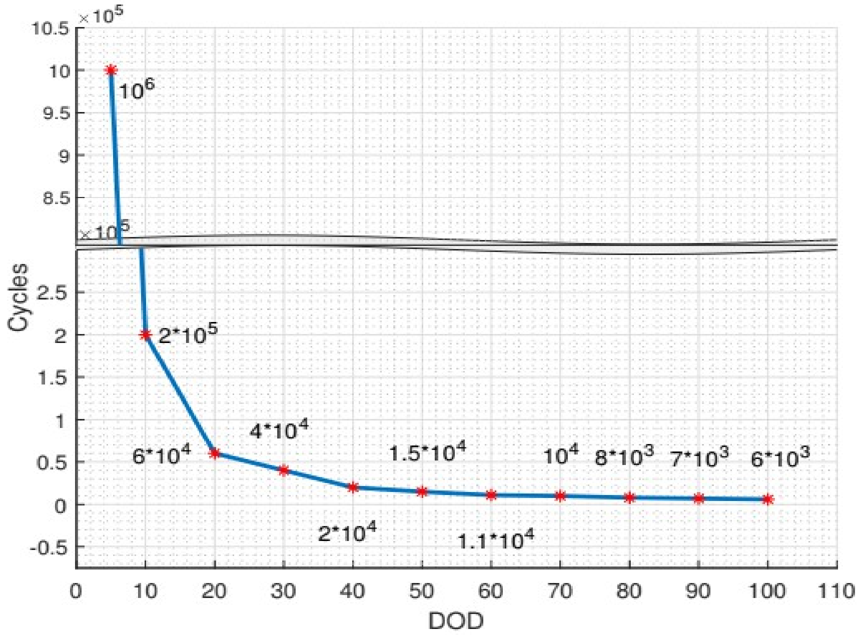

Figure 2

6.6 If need be, more studies and journals can be cited, all of which describe the reduction in achievable cycles brought about by increasing the DoD.

6.7 The Applicant has provided guidance on the intended DoD rates for this BESS in page 9 Statement of Common Ground with this Group REP2-108. That rate is 85%. When one compares that to the above two graphs, the first would suggest a lifespan of 8,500 cycles and the second 7,500. These two figures are actually higher than suggested by some other published papers and journals.

6.8 The Group's position has always been that the BESS will charge overnight from the grid. After all, the principal justification for this infrastructure is to balance out grid supply. Given that there may be a handful of days each year when charging cannot occur (possibly because of maintenance or component replacement issues), it would be fair to assume at least that the grid charging will occur 355 nights a year.

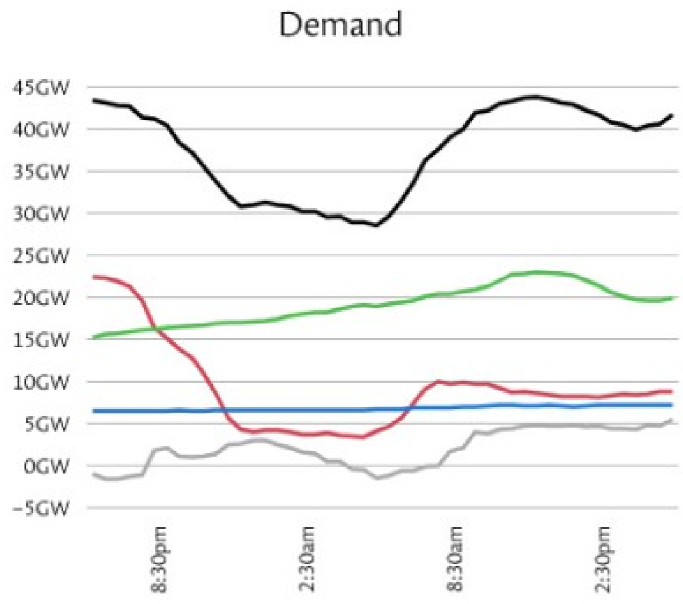

Figure 3

6.9 The above graphic, drawing on data from the National Grid showing demand overnight and into the day (30/01/26, from website grid.iamkate.com accessed 30/01/26), demonstrates the speed in the increase in demand for the morning peak and hence the need for increased generation and supply from storage.

6.10 As for calculating how many cycles are intended from solar charging, the Applicant has again assisted in that regard. In REP2-108, the Applicant has stated that for the greenhouse calculations, a depth of discharge/charge from solar would be 85%. 100% would be 880MWh so in the best year before any significant degradation in the BESS, a cycle would be 748MWh.

6.11 Table A15.1.19 in Technical Appendix REP2-075 (page 47) shows in year 1, 264,829MWh charged to the BESS from solar (and therefore 354 cycles of 748MWh), year 2 – 256,885MWh (343 cycles) and year 3-249,178 (333 cycles).

6.12 Thereafter, the amount charged annually to the BESS reduces, but due to degradation at the BESS, the total potential storage capacity also reduces so that 85% does not remain at 748MWh.

6.13 Combining the solar and grid powered cycles, a rough guide of annual aggregate cycles would be 680. Given that an 85% DoD would limit the total cycles to circa 8,000, that would mean the batteries would last 11-12 years. For the BESS to be still functioning up to year 40, that would require a replacement rate of 300%- the rate originally assumed by this Group.

6.14 Given the scientific data and published research, the Applicant's position that 50% of the cells will last 20-25 years is not tenable. To last that long the average DoD would have to be circa 58%. Such a DoD discharge would not be close to supplying the predicted annual MWh discharge to the grid. A 58% DoD would be 510MWh: 354 cycles at that rate would deliver 180,540MWh annually, as opposed to the Applicant's totals above (Y1-264,829MWh).

7 Battery Decommissioning Emissions.

7.1 A more worrying discrepancy with regard to the batteries has recently been discovered. The Applicant relies on page 2 of REP2-075 (and earlier versions) on the Rapier Report published on the website forbes.com[11] to calculate the embodied carbon for batteries. This is not challenged. Later in that report, Rapier indicates there will be a 4% loss between charge and discharge. This figure is also adopted in the Applicant's BESS calculations and the Group do not challenge its use either.

7.2 The Rapier report further addresses the end of life of Lfp batteries. It quantifies the decommissioning associated emissions to be 11kgCO2/kWh, drawing from the EU Product Environmental Footprint Category Rules. For some reason the Applicant did not adopt this figure on page 57 of REP2-075.

7.3 Instead the Applicant used a figure of 21.294kgCO_2/tonne, stating this is sourced from the Department for Business, Energy & Industrial Strategy, Greenhouse Gas Reporting: Conversion Factors, 2024. Checks have been made of that file (including using a ChatGPT search) to locate that factor. It is not anywhere in that database. This has now been agreed by the Applicant.

7.4 Using this figure on page 57 resulted in embodied decommissioning emissions of 407tCO_2. Adopting the Rapier report and using the EU Product Environmental Footprint Category Rules, then those emissions should be 24,200tCO_2. Following discussions with the Applicant, the correct factor has now been adopted by them and the figure below for the Applicant's production emissions has been amended accordingly on the assumption that the next Appendix A15 will have adopted this change.

The Applicant has stated that 21.294kgCO_2/tonne factor was sourced from the Byers Gill NSIP examination papers. This has been confirmed on the last page of Byers Gill Greenhouse Gas Assessment APP-123. It was not referenced and though clearly erroneous was not challenged in that examination. Alarm bells should have rung when in that document, the same decommissioning factor were used for steel and aggregate, and separately for batteries and plastic.

7.5 Below is a recalculation of the battery associated emissions given that it now seems inevitable that the replacement rate will have to be 300%. The initial construction and transport emissions remain the same.

Table 5

Phase	**Total tCO_2** (300% replacement)	**Applicant Total (tCO_2)**	**Net Increase over Applicant's figure (tCO_2)**
Replacement cells embodied carbon	939,840	469,920	469,920
Replacement Cells Transport	7,320	3,660	3,660
Decommissioning Embodied Carbon	38,720	24,200	14,520
Decommissioning Transport.	1,467	917	550
Total			**488,650**

7.6 Adding the new battery total to the revised panel total, **the production emissions must increase by 865,153tCO_2**

Since the publication of REP2-075 (which if one includes the PEIR version is the Applicant's third version of these calculations), the Applicant has agreed to amend another error on page 59. This has been done on the shared worksheets. The Applicant's total below includes this change even though at the time of writing, the latest version has yet to be submitted to the Authority. The total Emissions are now the Applicant's total -2,775,205 + 865,153 =**3,640,358tCO_2**

8 Misleading Attribution

8.1 Following the findings in 7.4 above, where the Applicant was sourcing the factor from the Byers Gill application papers, as opposed to the *"UK Government GHG Conversion Factors for Company Reporting" (2024, DESNZ),* but then stating the latter was the source, it was decided to further investigate other factors.

8.2 On page 49 of this Group's Climate Report REP1-102, it was pointed out that the tonne.km factor for shipping was wrong and this was accepted by the Applicant. The source was given as the above GHG Factors. However, on checking Byers Gill, the identical mistake was made on their page 4 of their earlier dated Greenhouse Gas Assessment APP-123. The chances of two independent analysts making this same mistake seems minute. The clear inference is that this was a copy paste from Byers Gill.

8.3 The Applicant throughout HGV transportation calculations has used a factor of 0.24kgCO_2 per tonne.km, giving the attribution as the GHG factors. This figure does not appear in the Freight HGV delivery factors in that database. This was discovered at an early stage. Their source was unclear but this Group did not seek to challenge it as it was in the ballpark of some of the database factors. The source now appears to be Byers Gill and that it is another copy paste from the same page as above.

8.4 In the Byers Gill Chapter 5 Climate Change APP-208, that Applicant does refer to the GHG Factors as a general source though in the Appendix, it is not clear which factors have been sourced from there.

8.5 The above points have been dealt with. The relevance of these copy pastes is that when this Applicant addresses the replacement rates for panels and batteries, these two are also copy pastes from Byers Gill. Had the GNR applicant investigated the lifespan scientific evidence, especially relating to the batteries, it is clear that the 150% rate for batteries had to be wrong. Just as if the Applicant had sourced the above factors from where they said they had, it would have been clear that the Byers Gill versions were wrong.

9 Net Emissions Savings

9.1 The following now represent the estimated impacts on greenhouse gasses from the construction, operation and decommissioning of this project.

Unlikely 2026 Pegged Emissions Scenario
Table 6

	tCO_2
Emission Savings	3,745,353
Production Emissions	3,640,358
Net Emission Savings	**104,995**

Group's Future Scenario
Table 7

Emission Savings	1,784,889
Production Emissions	3,640,358
Net Emission Savings	**-1,855,469**

DESNZ Modelling
Table 8

Emission Savings	977,721
Production Emissions	3,640,358
Net Emission Savings	**-2,662,637**

9.2 It can be seen that there is a marginal emissions benefit in the highly unlikely scenario but there are significant associated emissions predicted in the other two more likely models. Even if one disregarded the increased emissions associated with Group's increased replacement panels and cells, the project would still be a net contributor to increased greenhouse gasses.

10 Removal of the BESS

10.1 The Group have previously submitted arguments on what the impact would be of not including this second BESS in the design. Pages 16-17 of REP1-100 estimated the associated emissions for the BESS.

10.2 Since those reports, there have been significant design updates revealed and additional calculation errors uncovered. The net GHG savings in REP1-099 are now out of date.

10.3 Appendix E calculates the avoided emissions if all the panel generation left the intermediate substations and passed direct to the grid via the 400kv Staythorpe substation. That total is 693,333tCO_2. The revised BESS emission estimates are shown below:

Table 8

Material, activity or component	**tCO_2**
880,000kWh of Battery Cells embodied carbon (emissions factor sourced from Appendix APP-285 page 2. 300%replacement)	1,253,120
Cells HGV transport emissions	1,981
Cells sea journey emissions	7,780
Cells decommissioning	38,720
Cell decommissioning Transport	1,467
BESS Inverters (inc 150% replacement rate)	71,840
BESS Inverters transportation (sea from the Port of Shanghai and 2 HGV journeys)	2,902
BESS Inverter Steel Decommissioning	6
Inverter decommissioning transport	317
Estimated 2.5km of paladin security fencing around the BESS	163
Paint for fencing	34
palisade fencing around BESS substation	86
Sea Transport for that fencing	56
HGV transport for that fencing	25
Concrete (220 4MWh units x 15m²x 300mm plinths – 990m³ 2,475t) plus estimated 80 tonnes for substation foundations and concrete for fencing	267
Concrete Delivery	92
Concrete Decommissioning transport	29
Tarmac	226
Tarmac Delivery	104
Tarmac decommissioning (including transport)	56
Storage/Steel containers (Applicant estimates a maximum of 754 containers for the project. 2.2 tonnes each	4,495
Paint for containers	66
Total	**1,383,832**

Table Notes:The actual emissions total will be higher than the above total. Several constituent parts have not been included. These include some steel container transportation and decommissioning, loading/unloading of HGVs and ships, aggregate for tarmac road base, access tracks, geotextile membrane for tracks and substation (required under National Grid specifications), the substation grid transformer and mineral oil, workforce related emissions, diesel to power generators and construction machinery, cabling, firefighting water storage, and fire suppression systems.

Reducing the total project emissions of 3,640,358tCO_2 by the BESS emissions aggregated in Table 8 reduces production emissions to 2,256,526tCO_2.

Net Project Emissions With No Second BESS

Table 9

	tCO_2
Emission Savings	692,333
Production Emissions	2,256,526
Net Emission Savings	**-1,564,193**

10.5 Though the project is still a net producer of greenhouse gasses, the design of this project without a second BESS is the least harmful to the environment. The BESS of course does not generate any renewable energy. Clearly, an assessment needs to be made as to whether this is relevant to :

> *"5.3.9 The Secretary of State should be content that the applicant has taken all reasonable steps to reduce the GHG emissions of the construction and decommissioning stage of the development."*
> Source:Overarching National Policy Statement for Energy (EN-1)

11 Conclusions.

11.1 This report provides updates on the climate change impact of this project due to more design detail now being available. It also incorporates the latest amendments to the Technical Appendix A15 which correct recently discovered errors, identified since the Group's initial analyses.

This has been achieved as a result of valuable and helpful liaison with the Applicant's ES Consultant.

11.2 Whilst there is a lack of evidence that the battery cells are capable of lasting 20 odd years with high a DoD , there is industry accepted scientific research showing that the planned 85% DoD will limit the battery lives to 11-12 years.

11.3 The replacement rate for panels and batteries remain significant areas of disagreement. However, there also remains another divergence of views, in particular how using bifacial panels on grass can increase the power generation by a factor of 50% compared to the national average for solar farm generation.

11.4 It is possible that the publication of the original PVsyst date stamped report may shed some light on this question but the Applicant is not making this available. That said, PVsyst theoretical reports recently have tended to be the higher in assumed resultant predicted capacity factors, compared to the real world measurement by DESNZ.

11.5 Forgetting the various highly unlikely scenarios explored by the Applicant, it seems inevitable that this project will be a significant net contributor to greenhouse gasses. The design which would cause the least harm is where the panels link directly to the Staythorpe BESS, currently under construction.

11.6 It is inevitable that constructing a generation station of any type will involve associated emissions. However, the objective must surely be to adopt a design which at least is neutral on net emissions, and if that is not possible, then to choose a design which is the least harmful to the environment.

Appendix A
Solar Generation with replacement panels

Year Number	Year	Panels last 29 years	30yrs	31yrs	32yrs	33yrs	40yrs	Total MWh AC
1	2026	42283	42283	42283	42283	42283	211417	422,834
2	2027	63171	63171	63171	63171	63171	315856	631,712
3	2028	83131	83131	83131	83131	83131	415655	831,311
4	2029	82549	82549	82549	82549	82549	412746	825,492
5	2030	81971	81971	81971	81971	81971	409857	819,713
6	2031	81398	81398	81398	81398	81398	406988	813,975
7	2032	80828	80828	80828	80828	80828	404139	808,277
8	2033	80262	80262	80262	80262	80262	401310	802,619
9	2034	79700	79700	79700	79700	79700	398501	797,001
10	2035	79142	79142	79142	79142	79142	395711	791,422
11	2036	78588	78588	78588	78588	78588	392941	785,882
12	2037	78038	78038	78038	78038	78038	390190	780,381
13	2038	77492	77492	77492	77492	77492	387459	774,918
14	2039	76949	76949	76949	76949	76949	384747	769,494
15	2040	76411	76411	76411	76411	76411	382054	764,107
16	2041	75876	75876	75876	75876	75876	379379	758,759
17	2042	75345	75345	75345	75345	75345	376724	753,447
18	2043	74817	74817	74817	74817	74817	374087	748,173
19	2044	74294	74294	74294	74294	74294	371468	742,936
20	2045	73774	73774	73774	73774	73774	368868	737,735
21	2046	73257	73257	73257	73257	73257	366286	732,571
22	2047	72744	72744	72744	72744	72744	363722	727,443
23	2048	72235	72235	72235	72235	72235	361176	722,351
24	2049	71729	71729	71729	71729	71729	358647	717,295
25	2050	71227	71227	71227	71227	71227	356137	712,274

Year Number	Year	Panels last 29 years	30yrs	31yrs	32yrs	33yrs	40yrs	Total MWh AC
26	2051	70,729	70,729	70,729	70,729	70,729	353,644	707,288
27	2052	70,234	70,234	70,234	70,234	70,234	351,168	702,337
28	2053	69,742	69,742	69,742	69,742	69,742	348,710	697,420
29	2054	69,254	69,254	69,254	69,254	69,254	346,269	692,538
30	2055	84,313	68,769	68,769	68,769	68,769	343,845	703,234
31	2056	83,723	84,313	68,288	68,288	68,288	341,438	714,337
32	2057	83,137	83,723	84,313	67,810	67,810	339,048	725,840
33	2058	82,555	83,137	83,723	84,313	67,335	336,675	737,736
34	2059	81,977	82,555	83,137	83,723	84,313	334,318	750,021
35	2060	81,403	81,977	82,555	83,137	83,723	331,978	744,771
36	2061	80,833	81,403	81,977	82,555	83,137	329,654	739,558
37	2062	80,267	80,833	81,403	81,977	82,555	327,347	734,381
38	2063	79,705	80,267	80,833	81,403	81,977	325,055	729,240
39	2064	79,147	79,705	80,267	80,833	81,403	322,780	724,136
40	2065	78,593	79,147	79,705	80,267	80,833	320,520	719,067
							Total	**29,594,028**

Table Notes

The Applicant's formula was based on its maximum DC MWp output (1120MWp) as its baseline to create its most productive annual MWh theoretical year before degradation. The above figures have as their baseline the equivalent real world best year without degradation as 846,445MWh AC based on an maximum 800MW AC generation capacity. Columns 3-7 above all relate to 10% of the full array and represent replacements.

With year 3 being the most productive year, what might be expected is that that year would produce the 846,445MWh maximum as opposed to 831,331MWh as in the above table. However, just as the Applicant has done, the year 3 figure takes account of the 0.07% per annum degradation in the panels installed in the first 2 years.

The totals in this calculation do not take into account the Marginal carbon Intensity (kgCO2e/kWh) which will be applied in Appendix B. All figures are in MWh AC.

Appendix B

Carbon Avoidance: Panels (with BESS charging)

Year Number	Year	Marginal carbon Intensity kgCO2e/kWh	Annual Energy Production (Mwh) AC	Charged to BESS (MwhAC)	Solar Energy to Grid (Mwh) AC	Carbon Avoidance (tonnes CO2e)
1	2026	0.174	422,834	264,829	158,005	27,493
2	2027	0.154	631,712	256,885	374,827	57,723
3	2028	0.133	831,311	249,178	582,133	77,424
4	2029	0.11	825,492	241,703	583,789	64,217
5	2030	0.085	819,713	234,452	585,261	49,747
6	2031	0.0652	813,975	227,418	586,557	38,244
7	2032	0.0501	808,277	220,595	587,682	29,443
8	2033	0.0384	802,619	213,978	588,641	22,604
9	2034	0.0296	797,001	207,558	589,443	17,448
10	2035	0.0226	791,422	264,829	526,593	11,901
11	2036	0.0174	785,882	256,885	528,997	9,205
12	2037	0.0133	780,381	249,178	531,203	7,065
13	2038	0.0102	774,918	241,703	533,215	5,439
14	2039	0.0079	769,494	234,452	535,042	4,227
15	2040	0.006	764,107	227,418	536,689	3,220
16	2041	0.0057	758,759	220,595	538,164	3,068
17	2042	0.0036	753,447	213,978	539,469	1,942
18	2043	0.0028	748,173	207,558	540,615	1,514
19	2044	0.002	742,936	201,332	541,604	1,083
20	2045	0.0013	737,735	264,829	472,906	615
21	2046	0.0013	732,571	256,885	475,686	618
22	2047	0.0013	727,443	249,178	478,265	622
23	2048	0.0014	722,351	241,703	480,648	673
24	2049	0.0013	717,295	234,452	482,843	628
25	2050	0.0023	712,274	227,418	484,856	1,115
26	2051	0.0023	707,288	220,595	486,693	1,119
27	2052	0.0023	702,337	213,978	488,359	1,123
28	2053	0.0023	697,420	207,558	489,862	1,127
29	2054	0.0023	692,538	201,332	491,206	1,130
30	2055	0.0023	703,234	264,829	438,405	1,008
31	2056	0.0023	714,337	256,885	457,452	1,052
32	2057	0.0023	725,840	249,178	476,662	1,096
33	2058	0.0023	737,736	241,703	496,033	1,141
34	2059	0.0023	750,021	234,452	515,569	1,186
35	2060	0.0023	744,771	227,418	517,353	1,190
36	2061	0.0023	739,558	220,595	518,963	1,194
37	2062	0.0023	734,381	213,978	520,403	1,197
38	2063	0.0023	729,240	207,558	521,682	1,200
39	2064	0.0023	724,136	201,332	522,804	1,202
40	2065	0.0023	719,067	195,292	523,775	1,205
					Total	**454,445**

Appendix C
BESS Emission Savings.

1. Group's Future Scenario

Year Number	Year	Evening Peak Carbon Intensity (Gas Peaker) (kg CO2e/kWh)	Estimate charged to BESS (Mwh) AC	Energy Discharged to Grid (MWh)	Carbon Avoidance (tonnes) (tonnes CO2e)
1	2026	0.365	264,829	254,236	92,796
2	2027	0.365	256,885	246,610	90,013
3	2028	0.365	249,178	239,211	87,312
4	2029	0.365	241,703	232,035	84,693
5	2030	0.365	234,452	225,074	82,152
6	2031	0.365	227,418	218,321	79,687
7	2032	0.365	220,595	211,771	77,296
8	2033	0.365	213,978	205,419	74,978
9	2034	0.365	207,558	199,256	72,728
10	2035	0.365	264,829	254,236	92,796
11	2036	0.310	256,885	246,610	76,511
12	2037	0.264	249,178	239,211	63,083
13	2038	0.224	241,703	232,035	52,012
14	2039	0.191	234,452	225,074	42,884
15	2040	0.162	227,418	218,321	35,358
16	2041	0.138	220,595	211,771	29,152
17	2042	0.117	213,978	205,419	24,036
18	2043	0.099	207,558	199,256	19,818
19	2044	0.085	201,332	193,279	16,340
20	2045	0.072	264,829	254,236	18,269
21	2046	0.061	256,885	246,610	15,063
22	2047	0.052	249,178	239,211	12,419
23	2048	0.044	241,703	232,035	10,240
24	2049	0.038	234,452	225,074	8,443
25	2050	0.032	227,418	218,321	6,961
26	2051	0.027	220,595	211,771	5,739
27	2052	0.023	213,978	205,419	4,732
28	2053	0.020	207,558	199,256	3,902
29	2054	0.017	201,332	193,279	3,217
30	2055	0.014	264,829	254,236	3,597
31	2056	0	256,885	246,610	0
32	2057	0	249,178	239,211	0
33	2058	0	241,703	232,035	0
34	2059	0	234,452	225,074	0
35	2060	0	227,418	218,321	0
36	2061	0	220,595	211,771	0
37	2062	0	213,978	205,419	0
38	2063	0	207,558	199,256	0
39	2064	0	201,332	193,279	0
40	2065	0	195,292	187,480	0
				Total	**1,286,226**

2. DESNZ Modelling

Year Number	Year	Evening Peak Carbon Intensity (Gas Peaker) (kg CO2e/kWh)	Estimate charged to BESS (Mwh) AC	Energy Discharged to Grid (MWh)	Carbon Avoidance (tonnes) (tonnes CO2e)
1	2026	0.365	264,829	254,236	92,796
2	2027	0.323	256,885	246,610	79,666
3	2028	0.279	249,178	239,211	66,738
4	2029	0.231	241,703	232,035	53,541
5	2030	0.178	234,452	225,074	40,132
6	2031	0.137	227,418	218,321	29,860
7	2032	0.105	220,595	211,771	22,256
8	2033	0.081	213,978	205,419	16,547
9	2034	0.062	207,558	199,256	12,372
10	2035	0.047	264,829	254,236	12,053
11	2036	0.036	256,885	246,610	9,001
12	2037	0.028	249,178	239,211	6,674
13	2038	0.021	241,703	232,035	4,965
14	2039	0.017	234,452	225,074	3,730
15	2040	0.013	227,418	218,321	2,748
16	2041	0.012	220,595	211,771	2,532
17	2042	0.008	213,978	205,419	1,551
18	2043	0.006	207,558	199,256	1,170
19	2044	0.004	201,332	193,279	811
20	2045	0.003	264,829	254,236	693
21	2046	0.003	256,885	246,610	673
22	2047	0.003	249,178	239,211	652
23	2048	0.003	241,703	232,035	681
24	2049	0.003	234,452	225,074	614
25	2050	0.005	227,418	218,321	1,053
26	2051	0.005	220,595	211,771	1,022
27	2052	0.005	213,978	205,419	991
28	2053	0.005	207,558	199,256	961
29	2054	0.005	201,332	193,279	933
30	2055	0.005	264,829	254,236	1,227
31	2056	0.005	256,885	246,610	1,190
32	2057	0.005	249,178	239,211	1,154
33	2058	0.005	241,703	232,035	1,120
34	2059	0.005	234,452	225,074	1,086
35	2060	0.005	227,418	218,321	1,053
36	2061	0.005	220,595	211,771	1,022
37	2062	0.005	213,978	205,419	991
38	2063	0.005	207,558	199,256	961
39	2064	0.005	201,332	193,279	933
40	2065	0.005	195,292	187,480	905
				Total	**479,058**

Appendix D

Extracts from
"Investigation of Degradation of Solar Photovoltaics: A Review of Aging Factors, Impacts, and Future Directions toward Sustainable Energy Management"

Rahman et al (2023)

Manufacturers frequently offer warranties that guarantee a specific level of performance for a set period of time, sometimes 25 or 30 years, and that might provide insight into the predicted pace of degradation [27].

High temperature is a major cause of PV degradation. When a solar panel is exposed to high temperatures, it can cause several forms of damage that reduce the panel's efficiency and overall performance [28]. Some of the ways in which high temperatures can cause PV degradation include:

- Thermal stress: High temperatures can result in thermal stress inside the solar panel, which may cause the solar cells or other components to break or delaminate [29].
- Electrical resistance: The electrical resistance of the solar cells and interconnections increases with temperature, which can lower the efficiency of the panel [30].

Moisture can also be a cause of PV degradation. Moisture can enter the solar panel through various pathways, such as through cracks or defects in the panel's protective layers or through electrical contacts between cells [31]. Once inside the panel, moisture can cause several forms of damage that reduce the panel's efficiency and overall performance. Moisture can lead to PV degradation through the following mechanisms:

- Corrosion: Moisture can lead to the corrosion of the metal solar panel parts, including the frame and electrical connections. This may result in higher resistance and lower efficiency [32].
- Delamination: The materials used in solar panels, such as the encapsulant or back sheet, can delaminate as a result of moisture. This may cause the layers to separate, exposing the solar cells to moisture or other external elements [31].
- Electrical leakage: Moisture can also result in electrical leakage between solar panel cells or other components. This may result in decreased efficiency and a higher chance of electrical fires or failures [33].

PV deterioration can also be brought on by wind speed. Strong wind speeds can put the solar panel under mechanical stress, which can result in different types of damage that lower the panel's performance and efficiency [34]. The following are some ways that wind speed might lead to PV deterioration:

- Mechanical stress and vibration: Strong winds can bend or cause the solar panel to shake, which can put mechanical strain on the solar cells or other parts. This may cause the solar cells or other components to develop micro-cracks or delaminate, reducing the panel's power output [35].
- Structural damage: Damage to the solar panel's structure, such as the bending or deformation of the frame or supports, can also result from high wind speeds. This may result in the solar cells or other components being out of alignment, which will lower the panel's efficiency [36].

While it is often not as important a factor as temperature, moisture, or wind velocity, solar irradiance can also result in PV deterioration. The quantity of sunshine that strikes the solar panel is known as solar irradiance, and it has the potential to harm the panel in a number of ways that lower its overall performance and efficiency [37]. Solar irradiation can degrade PV in the following ways:

- Hotspots: When a portion of a solar cell is exposed to more sunlight than the rest of the cell, hotspots can form on the surface of the solar cell as a result of solar irradiance. This may result in localized cell damage and heating, which lowers the panel's overall power output. Several technologies, such as drone imaging, have been demonstrated to locate hotspots [38–40].
- Light-induced deterioration: When solar cells are exposed to sunlight for a lengthy period of time, they lose efficiency. Solar irradiance may also cause this type of deterioration. This can be influenced by the type of silicon used in the solar cells or by the presence of contaminants [41].

PV deterioration can also be brought on by the cell temperature. When exposed to sunlight, a solar cell transforms part of the energy into heat and some of it into electricity [42]. The solar cell's temperature may rise as a result of this heat, which may result in a number of types of damage that lower the cell's efficiency and overall performance.

- Light-induced deterioration: Long-term exposure to sunlight causes solar cells to lose efficiency. This kind of degradation might also be brought on by solar radiation. The kind of silicon used in the solar cells or the presence of impurities may have an impact on this [42].
- Thermal stress: Sudden temperature variations can put the solar cell under thermal stress, which can cause the micro-cracking or delamination of the cell or other components. Light- and elevated-temperature-induced degradation (LETID) can cause a decrease in the efficiency of solar cells, which leads to a decrease in the power output of the PV module. This decrease in power output reduces the overall energy production of the PV system and can result in lower financial returns. Additionally, LETID can also cause physical damage to the solar cells, such as cracking, delamination, and corrosion, which can lead to a shorter lifetime of the PV module. This might decrease the cell's power output and increase existing damage [29,43].

Citation: Rahman, T.; Mansur, A.A.; Hossain Lipu, M.S.; Rahman, M.S.; Ashique, R.H.; Houran, M.A.; Elavarasan, R.M.; Hossain, E. Investigation of Degradation of Solar Photovoltaics: A Review of Aging Factors, Impacts, and Future Directions toward Sustainable Energy Management. Energies 2023, 16, 3706. https://doi.org/10.3390/en16093706

Appendix E

Panel Carbon Avoidance with No BESS

Year Number	Year	Marginal carbon Intensity kgCO2e/kWh	Annual Production (Mwh)	Carbon Avoidance (TCO2)
1	2026	0.174	422,834	73,573
2	2027	0.154	631,712	97,284
3	2028	0.133	831,311	110,564
4	2029	0.11	825,492	90,804
5	2030	0.085	819,713	69,676
6	2031	0.0652	813,975	53,071
7	2032	0.0501	808,277	40,495
8	2033	0.0384	802,619	30,821
9	2034	0.0296	797,001	23,591
10	2035	0.0226	791,422	17,886
11	2036	0.0174	785,882	13,674
12	2037	0.0133	780,381	10,379
13	2038	0.0102	774,918	7,904
14	2039	0.0079	769,494	6,079
15	2040	0.006	764,107	4,585
16	2041	0.0057	758,759	4,325
17	2042	0.0036	753,447	2,712
18	2043	0.0028	748,173	2,095
19	2044	0.002	742,936	1,486
20	2045	0.0013	737,735	959
21	2046	0.0013	732,571	952
22	2047	0.0013	727,443	946
23	2048	0.0014	722,351	1,011
24	2049	0.0013	717,295	932
25	2050	0.0023	712,274	1,638
26	2051	0.0023	707,288	1,627
27	2052	0.0023	702,337	1,615
28	2053	0.0023	697,420	1,604
29	2054	0.0023	692,538	1,593
30	2055	0.0023	703,234	1,617

contd

Year Number	Year	Marginal carbon Intensity kgCO2e/kWh	Annual Production (Mwh)	Carbon Avoidance (TCO2)
31	2056	0.0023	714,337	1,643
32	2057	0.0023	725,840	1,669
33	2058	0.0023	737,736	1,697
34	2059	0.0023	750,021	1,725
35	2060	0.0023	744,771	1,713
36	2061	0.0023	739,558	1,701
37	2062	0.0023	734,381	1,689
38	2063	0.0023	729,240	1,677
39	2064	0.0023	724,136	1,666
40	2065	0.0023	719,067	1,654
			Total	692,333

Table Notes: The Production figures are taken from Appendix A. The marginal carbon intensity figures are identical to those used by the Applicant in Table A15.1.19 on pages 39- 41 of the Technical Appendix A15.1 – APP-285.

References and URL's

Reference Number	Citation or URL
1	https://www.pvsyst.com/pdf/common/general-conditions-of-use-english.pdf (accessed 20/01/26)
2	https://energy.sustainability-directory.com/learn/what-is-the-difference-in-energy-gain-between-monofacial-and-bifacial-panels (accessed 19/01/26)
3	https://insights.globalspec.com/article/24288/bifacial-solar-panels-are-they-worth-the-hype (accessed 19/01/26)
4	https://publica.fraunhofer.de/entities/publication/c24e5d26-2224-432f-b505-1b90e4d5ae08 (accessed 19/01/26)
5	Ghadeer Badran, Mahmoud Dhimish, A comparative study of bifacial versus monofacial PV systems at the UK's largest solar plant, *Clean Energy*, Volume 8, Issue 4, August 2024, Pages 248–260, https://doi.org/10.1093/ce/zkae043
6	"Reduction in CO_2 Emission through Photovoltaic System: A Case Study": (2017) Saurabh Kumar Rajput1 and Omveer Singh2, IEEE Senior Member EEED, ABES Engineering College, Ghaziabad, india1 EED, School of Engineering, Gautam Buddha University, Greater Noida, India
7	Citation: Rahman, T.; Mansur, A.A.; Hossain Lipu, M.S.; Rahman, M.S.; Ashique, R.H.; Houran, M.A.; Elavarasan, R.M.; Hossain, E. Investigation of Degradation of Solar Photovoltaics: A Review of Aging Factors, Impacts, and Future Directions toward Sustainable Energy Management. Energies 2023, 16, 3706. https://doi.org/10.3390/en16093706 (accessed 22/01/26)
8	https://www.anernstore.com/blogs/diy-solar-guides/depth-of-discharge-lifepo4-battery-life (accessed 22/01/26)
9	Cheng, Sandy & Liu, Yi-Hua & Hesse, Holger & Naumann, Maik & Truong, Cong & Jossen, Andreas. (2018). A PSO-Optimized Fuzzy Logic Control-Based Charging Method for Individual Household Battery Storage Systems within a Community. Energies. 11. 469. 10.3390/en11020469.
10	Garcia-Miguel,Alonso-Martinez,Gomez, Plaza and Asensio. (2022) A Review on the Degradation Implementation for the Operation of Battery Energy Storage Systems. MDPI
11	https://www.forbes.com/sites/rrapier/2020/02/16/estimating-the-carbon-footprint-of-utility-scale-battery-storage/ Forbes (2020).(accessed 8/12/25)