Gate Burton Energy Park
EN01031

Technical Note on Energy Yield Forecast Methodology
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1. Purpose of this Document

1.1.1 This document has been prepared on behalf of Gate Burton Energy Park Limited (the Applicant) following Issue Specific Hearing 3 – Session 1 on 23 August 2023 in the examination of the application for development consent for the Gate Burton Energy Park (the Scheme).

1.1.2 Specific Hearing 3 focussed on Carbon Saving including generating capacity/ electricity and the BESS. The purpose of this document is to provide further detail to the Examining Authority (ExA) on issues raised at Hearing 3, namely:

1. further details on the methodology for calculating the generating capacity for the Scheme, including details on the relationship between the generating capacity for the Scheme (531 MW) and the electricity supplied (i.e. 26.986 TWh); and
2. figures setting out the forecasted monthly and yearly energy output from the Scheme based on the illustrative site layout for the Scheme. This includes details of the energy accumulation over the Scheme's lifespan.

1.1.3 This document has been prepared on behalf of the Applicant by Skyray SAS (Skyray), as the Applicant's technical advisor on this subject, in collaboration with AECOM.

2. Energy Yield Forecast Methodology

2.1 Introduction

2.1.1 Generating capacity is not the same as electricity generation. The Scheme's estimated generating capacity is 531MW, but the actual electricity generated by the Scheme will depend on a number of factors (set out below). This section sets out how the estimate of overall electricity generated (26.986 TwH) has been calculated based on the Scheme's generating capacity of 531 MW.

2.1.2 Solar PV modules convert solar radiation (sunlight) to DC (direct current) electricity. Solar PV modules are characterised by a nominal or datasheet power, which is the power they are normally expected to produce at Standard Test Conditions (STC)[1]. The generating capacity of 531MW is based on the datasheet power for the solar PV modules and therefore represents their generating *potential*, rather than the actual electricity they will generate.

2.1.3 No power conversion process is 100% efficient and the conversion of solar radiation to medium or high voltage electrical power is no exception. Small losses occur at every stage of the solar PV plant power conversion process. These can be reduced and optimised but a good PV plant design accepts predefined levels of losses at different stages otherwise the cost becomes prohibitive or the efficacy of the overall design can be affected. Normal PV plant annualised overall conversion efficiencies are in excess of 80% (20% losses). Losses include:

- Incident light angle / reflection (seasonal and hourly)
- Shading (seasonal and hourly)
- Soiling (dirt and debris accumulation)
- solar PV module efficiency (low light behaviour)
- temperature (PV conversion is less efficient at higher temperatures)
- solar PV module quality, degradation, mismatch
- ohmic wiring losses; DC, LV, MV, transformation (electrical resistance and cable heating)
- inverter conversion efficiency; DC overload (power clipping), startup threshold.

[1] Standard test conditions are as follows: Photovoltaic cell temperature: 25C; Air Mass 1.5, Irradiance 1000W/m2. Typical solar PV module efficiency is ~21%.

2.1.4 Due to the difference between generating capacity and actual electricity yield, the Applicant also estimated the electricity yield for the Scheme. The rest of this document sets out how that estimate was calculated.

2.1.5 Solar PV Energy Yield forecasting is commonly used within the industry by owners and investors and is considered to be reliable and robust as an investment tool. There were 4 steps in the process used to forecast the electrcity generation for the Scheme (each step is discussed in further detail below):

- Solar Resource Estimation;
- Constructing the PV Plant and creating the shading scene;
- First Year Energy Yield Simulation(s); and
- Long Term Energy Yield Forecast.

2.1.6 For the Scheme, Skyray used industry standard tools for the process including Solargis Prospect, AutoCAD, Helios 3D and PVsyst.

2.2 Solar Resource Estimation

2.2.1 The first step in the methodology was to obtain irradiance data for the proposed Scheme location.

2.2.2 The solar resource (irradiation) data for the Scheme was sourced from Solargis Prospect which is a well-known system within the industry and is considered as a reliable source for irradiation data for projects in the development phase. Solargis Prospect provides Global Tilted Irradiance (GTI) (the energy received on the surface of the panels) based on many years of measuring solar irradiation both from satellite and ground-based measurement.

2.2.3 For the Scheme site and illustrative design, the monthly Solargis Prospect Global Tilted Irradiance data for the installed PV Module design for a typical year in the Scheme's location (Lat: -53.34°N / Long: -0.73°W) is shown in Table 1 below:

Table 1 - Solargis Prospect Irradiation

Month	GTI - Global Titled Irradiation (kWh/m^2)	Month	GTI - Global Titled Irradiation (kWh/m^2)
January	29.2	July	149.6
February	50.4	August	128.4
March	88.4	September	96.3
April	121.0	October	63.9

Month	GTI - Global Titled Irradiation (kWh/m^2)	Month	GTI - Global Titled Irradiation (kWh/m^2)
May	151.3	November	35.9
June	144.0	December	25.6
Total			1084.1

2.2.4 Solar PV Plants react differently to sunny and cloudy days and so rather than providing an average, Solargis Prospect supplies irradiance data as a collection of measured days from previous years for each specific month which in total combine to provide the expected monthly irradiation for the location. This ensures that the generation of the PV Plant from the simulation in the section below more accurately reflects the actual irradiation pattern than an average.

2.2.5 As noted in the Applicant's Response to ExA First Written Questions Q 1.1.15 **[EN010131/APP/8.6]** inland solar irradiation is very consistent in the same geographic area with the variation of a 42km x 42km area around the Scheme being less than 3%.

2.3 Constructing the Solar Park and Creating the Shading Scene

2.3.1 The second step in the methodology was to create the design/layout of the solar park for the Scheme.

2.3.2 Skyray created the solar park in AutoCAD software including external information contained within the topographic survey and then used Helios 3D to create a shading scene for the Scheme. This shading scene is used by PVsyst to simulate the effect of near shading (related to the project) and far shading (related to the environment around the project). In complex topography projects, shading can be significant but for the Scheme, which is quite flat, shading is more limited.

2.4 Energy Yield Simulation(s)

2.4.1 The third step in the methodology was to calculate the estimated energy yields based on the irradiance data and the design of the solar park (as described above). Skyray used the well-recognised simulation software PVsyst to create the forecasted yield.

2.4.2 The Scheme is a large project and so to run the simulation, it was necessary to split the Scheme into four sections, to simulate each section and then to aggregate the results. This is not expected to have had any effect on the final yield figures.

2.4.3 In addition to the AutoCAD and Helios 3D shading scene described above, the main equipment used (PV Modules and Inverters) together with the method of combining the equipment together (PV Modules into Strings and Strings to inverters) and expected losses based on other projects were input into the simulations.

2.4.4 The simulations were then run for each of the four sections and the results aggregated resulting in a first-year forecasted specific yield as per Table 2 below:

Table 2 – First Year Simulation Results

Month	GTI (kWh/m^2)	Specific Yield (kWh/kWp)	Month	GTI (kW/m^2)	Specific Yield (kWh/kWp)
January	29.2	21.1	July	149.6	128.3
February	50.4	40.9	August	128.4	110.0
March	88.4	78.7	September	96.3	83.2
April	121.1	106.9	October	63.9	53.8
May	151.3	132.2	November	35.9	25.7
June	144.0	124.4	December	25.6	17.0
Total				1084.1	922.2

2.4.5 Note that the simulation was run on a slightly larger scheme than the one ultimately applied for, because reductions were made to the number of PV Modules installed to reflect constraints on the site during the final development phase. The impact, if any, would be a slight increase in Specific Yield above 922.2kWh/kWp, because the change in the scheme design also reduced some potential losses (such as shading that was present in the area of panels removed from the Scheme)

2.5 Long Term Energy Forecast

2.5.1 Finally, Skyray calculated the long term energy forecast for the Scheme. This is done to accommodate for any degradation in output of the PV panels over the lifetime of the Scheme.

2.5.2 The methodology for long term energy forecast for carbon savings is described in the Applicant’s Response to ExA First Written Questions Q1.4.2 **[EN010131/APP/8.6]** but to summarise, a degradation of 2% was applied for year 1 and a further 0.45% for each year thereafter.

2.5.3 It was then assumed that there would be a full replacement of the PV modules in year 30 and the same degradation values would apply thereafter.

2.5.4 These standard assumptions are based on existing PV technology. It is likely that annual yields and degradation rates will improve with continued development of PV panels. Further, as the climate warms, it is likely that reduced cloud cover may result in increased yields in the future. For these reasons, the assumptions relating to lifetime output can be seen as inherently conservative.

2.5.5 This results in the annual generation figures as shown in **Error! Reference source not found.** and **Error! Reference source not found.** and **Error! Reference source not found.**. Table 3 also confirms the projected total lifetime generation for the Scheme, which is estimated to be 26.986 terawatt hours (TWh) of electricity.

Table 3 – Long Term Energy Forecast

Year	Degradation	Specific Yield kWh/KWp	kWp	Annual Yield (MWh)	Aggregate Yield (MWh)
0	0.00%	922.0	531,000		
1	2.00%	903.6	531,000	479,790	479,790
2	0.45%	899.5	531,000	477,631	957,422
3	0.45%	895.4	531,000	475,482	1,432,904
4	0.45%	891.4	531,000	473,342	1,906,246
5	0.45%	887.4	531,000	471,212	2,377,458
6	0.45%	883.4	531,000	469,092	2,846,550
7	0.45%	879.4	531,000	466,981	3,313,531
8	0.45%	875.5	531,000	464,879	3,778,410
9	0.45%	871.5	531,000	462,788	4,241,198
10	0.45%	867.6	531,000	460,705	4,701,903
11	0.45%	863.7	531,000	458,632	5,160,535
12	0.45%	859.8	531,000	456,568	5,617,103
13	0.45%	856.0	531,000	454,513	6,071,616
14	0.45%	852.1	531,000	452,468	6,524,084
15	0.45%	848.3	531,000	450,432	6,974,516
16	0.45%	844.5	531,000	448,405	7,422,921
17	0.45%	840.7	531,000	446,387	7,869,308
18	0.45%	836.9	531,000	444,378	8,313,687
19	0.45%	833.1	531,000	442,379	8,756,066
20	0.45%	829.4	531,000	440,388	9,196,454
21	0.45%	825.6	531,000	438,406	9,634,860
22	0.45%	821.9	531,000	436,433	10,071,293

Year	Degradation	Specific Yield kWh/KWp	kWp	Annual Yield (MWh)	Aggregate Yield (MWh)
23	0.45%	818.2	531,000	434,470	10,505,763
24	0.45%	814.5	531,000	432,514	10,938,277
25	0.45%	810.9	531,000	430,568	11,368,845
26	0.45%	807.2	531,000	428,631	11,797,476
27	0.45%	803.6	531,000	426,702	12,224,178
28	0.45%	800.0	531,000	424,782	12,648,959
29	0.45%	796.4	531,000	422,870	13,071,829
30	0.45%	792.8	531,000	420,967	13,492,796
31	2.00%	903.6	531,000	479,790	13,972,587
32	0.45%	899.5	531,000	477,631	14,450,218
33	0.45%	895.4	531,000	475,482	14,925,700
34	0.45%	891.4	531,000	473,342	15,399,042
35	0.45%	887.4	531,000	471,212	15,870,255
36	0.45%	883.4	531,000	469,092	16,339,346
37	0.45%	879.4	531,000	466,981	16,806,327
38	0.45%	875.5	531,000	464,879	17,271,207
39	0.45%	871.5	531,000	462,788	17,733,994
40	0.45%	867.6	531,000	460,705	18,194,699
41	0.45%	863.7	531,000	458,632	18,653,331
42	0.45%	859.8	531,000	456,568	19,109,899
43	0.45%	856.0	531,000	454,513	19,564,412
44	0.45%	852.1	531,000	452,468	20,016,881
45	0.45%	848.3	531,000	450,432	20,467,313
46	0.45%	844.5	531,000	448,405	20,915,718
47	0.45%	840.7	531,000	446,387	21,362,105
48	0.45%	836.9	531,000	444,378	21,806,483
49	0.45%	833.1	531,000	442,379	22,248,862
50	0.45%	829.4	531,000	440,388	22,689,250
51	0.45%	825.6	531,000	438,406	23,127,656
52	0.45%	821.9	531,000	436,433	23,564,090
53	0.45%	818.2	531,000	434,470	23,998,559
54	0.45%	814.5	531,000	432,514	24,431,074
55	0.45%	810.9	531,000	430,568	24,861,642
56	0.45%	807.2	531,000	428,631	25,290,273
57	0.45%	803.6	531,000	426,702	25,716,974
58	0.45%	800.0	531,000	424,782	26,141,756
59	0.45%	796.4	531,000	422,870	26,564,626
60	0.45%	792.8	531,000	420,967	26,985,593

Figure 1 - Gate Burton Annual Yield

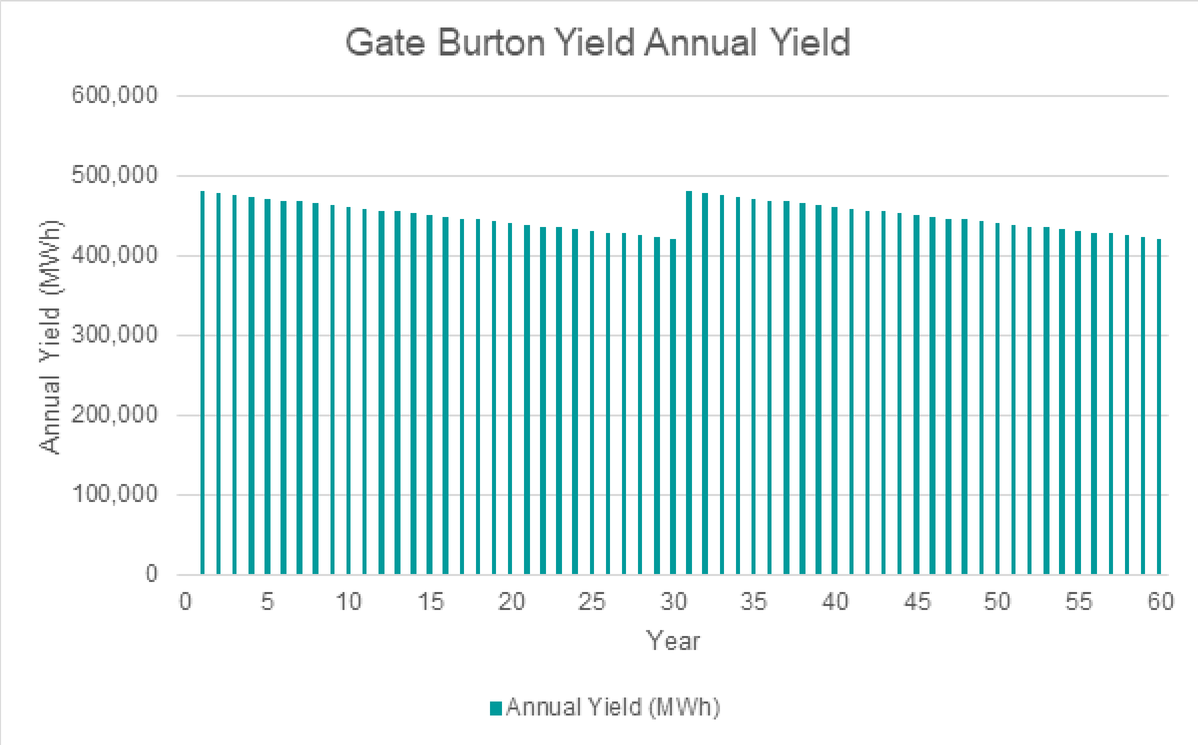
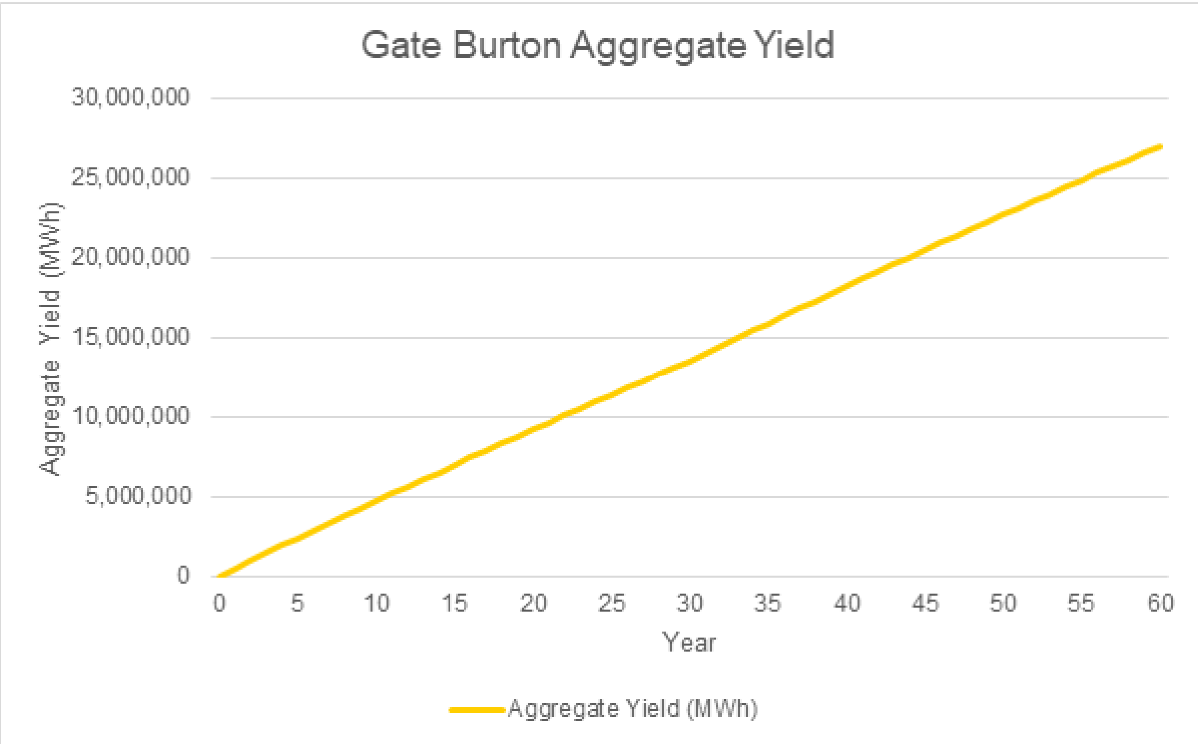


Figure 2 - Gate Burton Aggregate Yield



3. Summary

3.1.1 This document sets out the methodology adopted to calculate the likely electricity supplied by the Scheme. Whilst the overall generating capacity of the Scheme is 531 MW, various factors are then applied to calculate the actual electricity generated (in this case, 26.986 TwH over the Scheme's lifetime).

3.1.2 No power conversion process is 100% efficient and the conversion of solar radiation to medium or high voltage electrical power is no exception. There are also various factors which might affect electricity generation during the Scheme's lifetime, as set out above. However, the Applicant has estimated the likely electricity that will be generated by the Scheme using industry recognised processes and tools to calculate an informed figure.