Review of the Applicant's Technical Note [REP3-038].

The Applicant's response to the ExA request at ISH2 for a Technical Note was submitted at Deadline 3. The narrative and figures are mostly from previous submissions, although there are new details and insights.

The information provided does not dispel concerns around the technical merits of the proposal. Rather, it reinforces the concern that fundamental technical issues are being misunderstood, and it introduces inappropriate application of simulation methods in PVsyst.

1. *New Information*.

1.1 [4.1.1] The Applicant used PVsyst to design the layout and simulate the scheme using precise field geometry and forecast radiance levels specific for the site.

1.2 [4.1.4–5] The plan is now for 828,900 panels of 580 Wp each (total 480.8 MWp). PVsyst simulation predicts 663.5 kWh/yr per panel, thus 549.8 GWh/yr for the whole farm. This corresponds to a Load Factor of 13%, which is normal for solar and other renewables.

1.3 [4.1.6] A graph (Figure 2) is included to show daily energy production spanning one year based on irradiance data from 1990.

1.4 [5.1.5] There are 27 PV panels per motor [implying a total of over 30,000 motors].

1.5 [5.1.7] Figure 3 (Fig 6-6 in the Statement of Need) demonstrates that SAT yields 15% more energy than FSF at an overplanting ratio of 1.2.

1.6 [5.1.8] PVsyst simulation shows that SAT yields 12.3% more energy that FSF:
SAT: 663.5 kWh/yr (one panel), 549.8 GWh/yr (whole farm)
FSF: 591.0 kWh/yr (one panel), 489.8 GWh/yr (whole farm)

1.7 [6.1.1–14] The Applicant recalculates the land take, relying to a great extent on the methodology used by Mallard Pass Solar Farm (DCO recently awarded).

2. <u>Flaws in the Technical Note</u>

2.1 *<u>Evaluation of SAT annual energy yield</u>* [4.1.4–5]

2.1.1 The Applicant evaluates the total energy yield by simulating the energy from an isolated panel (in PVsyst) and multiplying this by the number of panels.

This is not a valid simulation methodology.

Just as in the real world, a simulated isolated panel outperforms a panel in an array because it is not curtailed by all the *in situ* losses: self-shading (adjacent panel tables), environmental shading (hedgerows etc), panel mismatch in the strings, DC cable resistance, inverter losses, overplanting loss (clipping), downstream AC losses (in our case, the transformers and the long corridor run), etc. This results in a significantly inflated estimate of solar farm yield.

The Applicant's attention is drawn to the PVsyst website and its excellent YouTube channel, where a wealth of information on loss simulation and the correct use of their software can be found.

2.1.2 Furthermore, if the Applicant had indeed made/simulated the claimed model in PVsyst including the "*precise field geometry and forecast* [sic] *irradiance levels*" [4.1.1], they would already have the farm's annual energy value. It's the first number in the PVsyst Results window.

2.1.3 The Applicant correctly calculates 13% as the Load Factor[1], based on 480 MW and 549.8 GWh/yr [4.1.5]. The Applicant considers this value 'normal' for solar and other renewables.

If you have a passing interest in renewables technology you will be aware that Load Factors vary considerably across the various technologies: solar 10.8%, onshore wind 24.5%, offshore wind 40.3% (2023 data; <u>DUKES 6.3</u>).

2.1.4 The new graph [Figure 2, 4.1.6] based on 1990 meteorological data is a surprising addition. As PVsyst explains, you cannot select a particular year for meteorological data: meteo files are compiled by amalgamating data from ten or more years. (And, why would you choose 1990?)
A handy feature of PVsyst though is the ability to download data files into Excel, where you can re-annotate graph axes to suit your documentation requirements.

If, like me, you lack experience with PVsyst, you might not be aware that

> **The year 1990**
> In PVsyst, we have adopted the convention to label all data which don't correspond to really measured data at a given time as 1990. This is the case, namely, of all synthetic hourly data or TMY data files.

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[1] Load Factor = annual energy / (installed capacity x 24 x 365)

2.2 *SAT yields 12.3% higher energy compared to FSF* [5.1.7–8]

2.2.1 The PVsyst-derived value for the SAT/FSF advantage, 12.3%, is similarly the victim of an unacceptable simulation methodology.

In this instance, the Applicant neglects the fact that SAT is particularly susceptible to shading losses. (Shading computation is, by its very nature, absent from single-panel simulation.)

FSF collects most energy around the middle of the day, because it is orientated to face the sun at this time. In the early morning and late evening FSF energy collection is minimal, thus shading (most prominent in the morning and evening) is relatively benign. In contrast, SAT sacrifices some midday energy in exchange for enhanced collection throughout daylight hours. However, this renders it significantly more susceptible to shading losses.

The Applicant's use of single-panel simulation goes some way to explain the difference from the relatively modest SAT advantage (2-3%) predicted by PVwatts.[2]

2.2.2 The high SAT/FSF ratio is potentially supported by the scientific analysis provided in the Statement of Need [and here, 5.1.7], which demonstrates a figure of 15%.

The Applicant's analysis is reviewed in the Appendix (below). From a practical standpoint, the analysis lacks credible scientific merit.

2.2.3 Further support for SAT is that it is supposedly specified in at least eight NSIP proposals [5.1.1–2]. Five are mentioned by name.

Cottam is indeed SAT. Byers Gill is FSF. The remaining three are currently undecided (SAT or FSF), including Mallard Pass, which has been awarded a DCO.

3. *Land Use Efficiency* [6.1.1–16]

3.1 "*During the ISH the ExA suggested that the ratio should be based on MW ac export and including the ecology mitigation land and grid connection corridor*" [6.1.3].

3.2 No. The ExA pointed out that EN-3 requires that export power (AC) be used in the calculation of land take, not installed capacity (DC). He suggested that fencing and PRoW be included in the land calculation, not ecology mitigation land or the grid connection corridor [timestamp 21:27 to 21:58, Session 2].

[2] US Gov. National Renewable Energy Laboratory (NREL): https://pvwatts.nrel.gov/pvwatts.php

3.3 The high land-take value (6.2 acres/MW) is based on the land classification provided in the Statement of Reason [1.3.2, APP/4.1; areas in hectares]. Areas excluded from the calculation are shown here in green:

Solar PV plus substations	966.4
Ecology Mitigation	107.9
Interconnecting Cables	23.5
Grid Corridor (to NG Drax)	168.9
Access routes to site	9.77
TOTAL (solar farm complex)	1000
TOTAL (excluded)	277
TOTAL (ORDER LIMIT)	**1277**

1000 ha (2471 acres) for 400 MW (AC) equates to 6.2 acres/MW

3.4 In the Technical Note, the Applicant has classified land by Works number and assigned each an area (hectares).

#1	Solar PV	748.7	(including fencing and PRoW)
#2	Substations	2.0	
#3	Grid Corridor (to NG Drax)	261.1	
#4	*General Works*	*95.8*	(see 3.5.2)
#5	Compounds	27.6	
#6	Maintenance building	0.3	
#7	Access routes	14.0	
#8	Ecology Mitigation	126.5	
TOTAL (solar farm complex)		765	
TOTAL (excluded + *General Works*)		*511*	
TOTAL (ORDER LIMIT)		**1276**	

765 ha (1891 acres) for 480 MW (DC) equates to 3.9 acres/MW (DC)

3.5 There are evident discrepancies between the calculations.

3.5.1 The statement that the eight Works areas are “distinct” [6.1.6] is incorrect – their sum exceeds the total of the Order Limit. For example, General Works (Works #4) includes the Grid Connection Corridor [6.1.6] and/or the Construction and Decommissioning Compounds (according to the dDCO).

3.5.2 Hence, the General Works value is adjusted in the table (above) from the reported 1016.4 ha to 95.8 ha, in order that the sum of areas equals the Order Limit.

3.5.3 Solar PV + Substations area has decreased by 22% since the Statement of Reason.

3.5.4 Ecology Mitigation has increased by 17%; the Grid Corridor has increased by 55%.

3.5.5 There is no obvious reason why the Compounds should be excluded, particularly as they are now declared potential sites for PV [6.1.6e]. General Works should probably be included also.

3.5.6 The Applicant contends that it should be allowed to use Installed Capacity (480 MW) in the calculation because Mallard Pass got away with it [6.1.7]. This is not a compelling argument. Also, Mallard came in at a respectably efficient 2.9 acres/MW according to paragraph 3.2.84[3] in its ExA report. Moreover, Mallard is using overplanting at a commendable ratio of 1.45 [3.2.99].

3.6 If the proposal had included a battery facility – as is almost universal for NSIP proposals these days – the land-take figure would be even higher.

3.7 It is unlikely that the hectare values in the Statement of Reason were the victims of wholesale unexplained auditing errors.

4 *Installed Capacity*

4.1 The ExA invited the Applicant to address the question of SAT Installed Capacity with a 1.2 overplanting ratio and system losses [47:30 in Session 2; see also REP3-069, last page].

4.1.1 The Applicant reasserts that 400 × 1.2 = 480 [2.1.2]. In a related response [REP3-033, page 33] to concern over power calculations, the Applicant suggests contacting PVsyst to find out what algorithm they use. This sheds some light on the Applicant's confusion concerning the distinction between electrical ENERGY and electrical POWER.

.4.1.2 PVsyst is a computationally intensive simulator of ENERGY production and loss (one calculation per hour over a span of one year). It does not compute POWER loss because it does not need to.

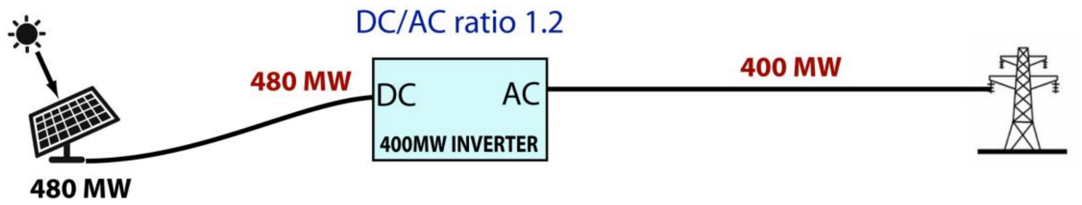
In contrast, simulation is not required to determine peak POWER values. This is a number you work out with the assistance of a calculator and knowledge of the electrical characteristics of the particular solar installation.

4.1.3 The Applicant's calculus (480 MWp gives you 400 MW export) suggests a failure to comprehend fundamental concepts in solar electrical design. In a final attempt to illustrate what I had naively assumed would be obvious to a solar engineer, consider the following imaginary school Physics question.

[3] The relevant paragraph is 3.2.84 not 8.2.84.

Q. What equipment is required for 400 MW grid export with 1.2 overplanting?
(Hint: The technical term for overplanting is 'Inverter DC/AC Ratio.')

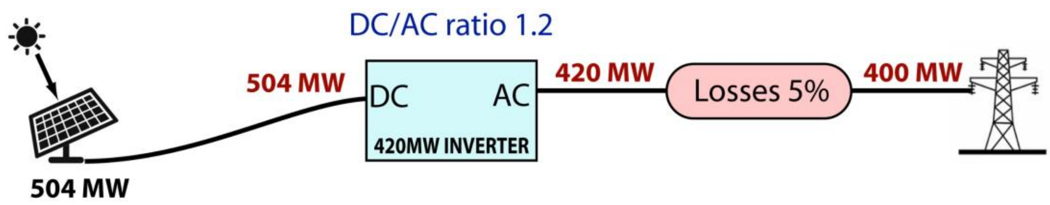
A. (GCSE):



A ratio of 1.2 means that 20% more panels will need to be installed than the output rating. 400 MW × 1.2 = 480 MW.

You will need 480 MW PV and a 400 MW Inverter.

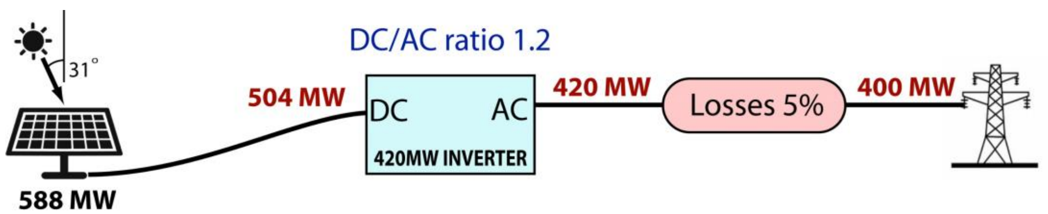
A. (A Level):



Assume power losses of 5% in the AC pathway for transformers and 8 km cables. (For simplicity, we will ignore DC losses such as inverter, PV temperature, panel mismatch and cable resistance.) The Inverter rating must be 400 MW + 5% = 420 MW.

For a 1.2 DC/AC ratio, the peak Inverter input power will need to be 420 MW × 1.2 = 504 MW.

Assuming PV panels achieve their rated output under direct sunlight (FSF),
504 MW of PV will be required with a 420 MW Inverter.



Maximum sun elevation in Yorkshire is 59°. If the panels are horizontal (SAT), the peak irradiance received will be reduced by a factor of *cos* (31°). Thus, the PV capacity will need to be increased by the same factor: 504 MW ÷ *cos* (31°) = 588 MW.

You will require 588 MW of PV with a 420 MW Inverter.

Appendix. Figure 3 (Figure 6-6 in the Statement of Need)

The PVsyst simulated performance advantage (12.3%) of SAT over FSF [5.1.8] is supported by the graphical analysis presented in Figure 3 (Figure 6-6 in the Statement of Need), with a measured SAT advantage of 15% [5.1.7].

In fact, careful measurement of the graphical data elicits an energy advantage 13.3% at 1.2 overplanting, which is an even better match to the declared PVsyst value.

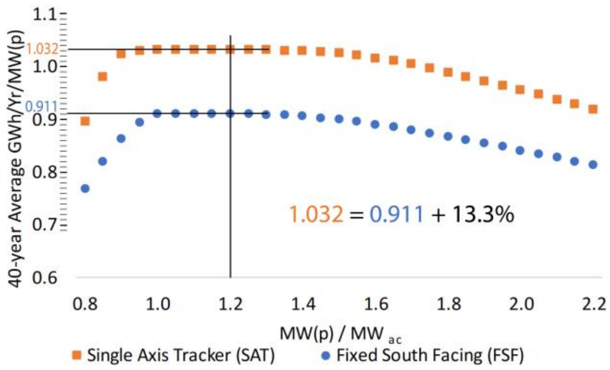


Figure 6-6 in Statement of Need © BOOM

However, there are features of these curves that call into question the integrity of the presented graphical data.

A.1 Most glaringly, the curves have the wrong shape. We cannot test the absolute values, but we can be certain that the energy-per-panels value will reach a maximum at 1.0 and remain at that level as the ratio decreases further (i.e. a horizontal line in graphical representation). No explanation has been offered for the droop below 1.0.

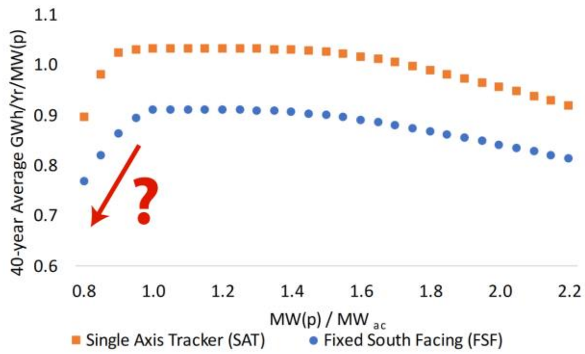
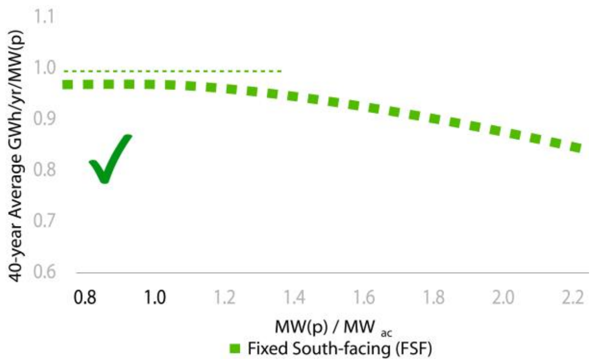


Fig 6-6 in Statement of Need © BOOM Power Ltd



Energy-per-panels without droop below 1.0

A.2 If a graph is presented as scientific evidence the source of its data must always be specified, otherwise the curious reader may wonder if data points are being made up. The only information is "*derived from inputs which are appropriate for all solar schemes generally*" [Statement of Need, 6.6.24], which is patently impossible. Inputs into what? From where? If nothing else, we know that the SAT–FSF graphical offset will vary considerably between different solar schemes, depending on latitude.

A.3 There are artifacts in the graph that one commonly associates with hand-drawn curves. For example, the droop (for whatever reason) starts at 1.0 for FSF. But the equivalent point for SAT has shifted to nearer 0.9 (red): visually more appealing, but how is this scientifically possible? And, how is it that overplanting has zero detectable effect on SAT 40-year panel yield until planting exceeds 1.3 (green)?

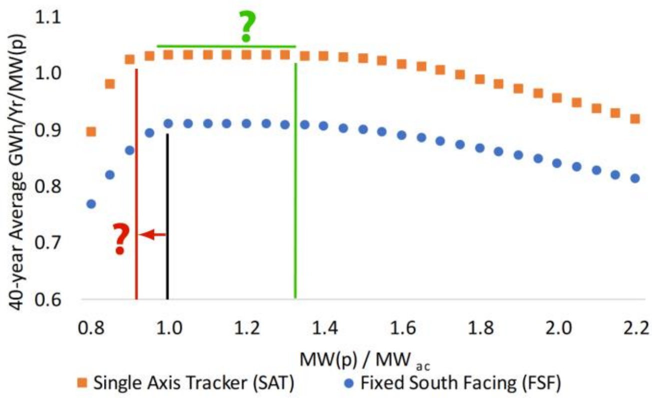
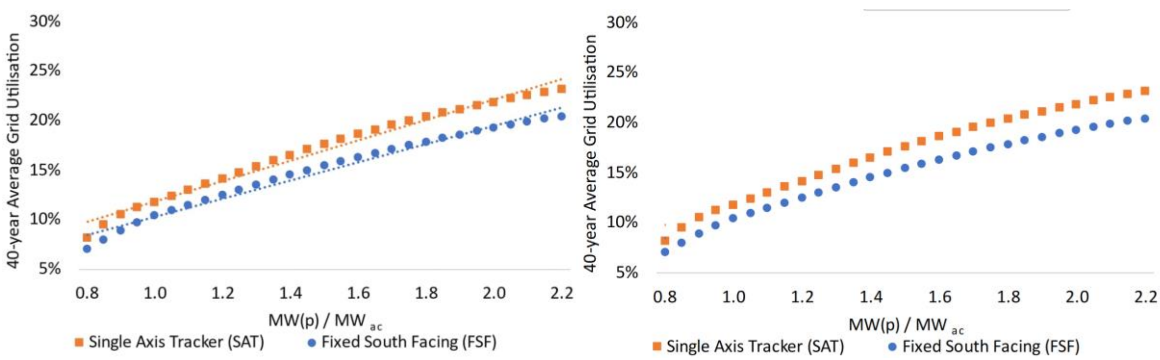


Fig 6-6 in Statement of Need © BOOM Power Ltd

A.4 Related figure: The discredited [REP2-026] "*straight lines of best fit*" in Fig 6-5 have been discretely removed in the latest revision of the Statement of Need.



Figs 6-5 in Statement of Need: original (left) and Rev 01 (right) © BOOM Power Ltd

This editing must have been performed in haste. The associated paragraphs [6.6.29, 6.6.30] still draw conclusions from the (now non-existent) straight lines of best fit. These paragraphs too should be removed.