Summary Statement

1. Unresolved Technical Issues

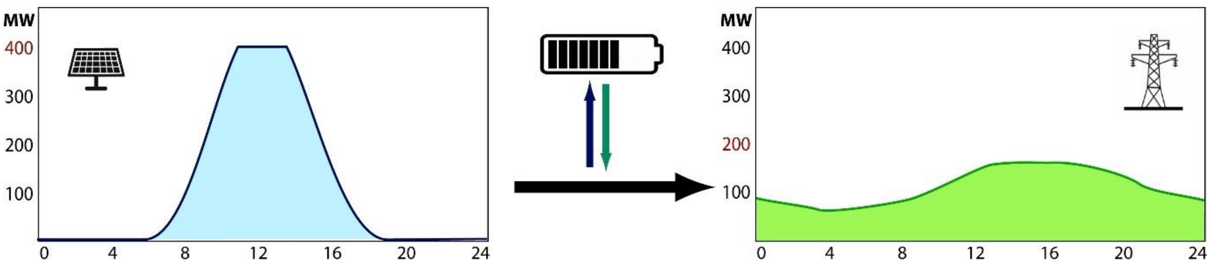
1.1 Batteries not Included

The East Yorkshire proposal differs from those of most other solar NSIPs in that it excludes a battery (BESS). The Applicant refers to five such proposals in its comparison of Carbon Intensity data [REP1-081, p29]. All five include a BESS. East Yorkshire is not unique in this respect, though: Mallard Pass was recently approved by the SoS without a battery.

The design had originally included a 'DC-coupled' battery.[1] This option was abandoned because of difficulties with the necessary fire-suppression water system and/or visual prominence, and following consultation feedback [Rsp to ExQ1 Q.1.4.1].

1.1.1 The Role of the Battery (Summary of REP1-111 p2)

The battery allows energy generated in the middle of the day to be exported when required. Thus, it can convert the PV generation profile to match the grid's Demand profile.



1.1.2 Additional benefits

1) A battery reduces a farm's required export power rating by over 50% for the same amount of energy (diagram above). This translates into reduced cost of the transformers, switchgear and grid corridor. Most significantly, the NG contract capacity can be halved. Grid capacity is identified as the limiting technical constraint for the Net Zero grid.

2) When solar generation is lower (in winter it is <10% of peak), an AC-coupled battery can be used for grid balancing. This provides the owners with essential out-of-season income to offset the battery investment.

[1] DC-coupled: on the PV panel side of the Inverters. An AC-coupled solar battery can also be used for grid balancing. However, the East Yorkshire NG agreement is Export-only.

1.1.3 Historical context

Early solar PV farms did not require a battery, because the generation could be (and still is) complemented by natural gas generation when solar output is low/off. Also, lithium batteries were prohibitively expensive ten years ago. Once the Net Zero grid is achieved (2030 according to the current government), there will be no fast-response alternative source to complement native solar output.

Domestic rooftop PV in0stallations have routinely included a battery for many years.

1.1.4 The Applicant's position

The Applicant investigated the potential for a co-located battery and is thus NPS EN-1 compliant.
Another developer could construct a battery facility in the vicinity of the Scheme.
There is an urgent need for solar PV development.
There is a precedent: Mallard Pass was recently awarded a DCO without a battery.
[Rsp to ExQ1 Q.1.4.1 and Rsp to D2, p20]

1.1.5 Summary opinion

First-generation solar PV farms did not require a battery. For Net Zero, associated energy storage will be obligatory.
An integrated battery allows a solar installation to satisfy load demand while alleviating the NG burden by reducing peak capacity. An AC-coupled battery represents the holistic energy solution, as this additionally allows grid balancing off-season.

Economically, a solar farm lacking a battery will suffer from its narrow window of power generation (a few hours) in a competitive hourly energy marketplace.

The Applicant's suggestion of a battery facility as a separate installation is reviewed below.

The Mallard Pass ExA report [3.2.110], uniquely, assessed the lack of a battery as a "neutral factor," and noted that NPS does not require one [3.2.160]. The examiners did not wish to "delay the point at which energy is generated."
The East Yorkshire ExA is encouraged to examine the evidence *de novo* and arrive at its own conclusion.

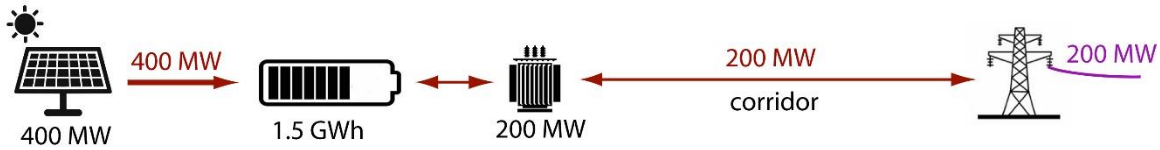
1.2 Solar battery location

The Applicant's position that there is nothing *prohibiting other developers coming forward with their own storage projects in the vicinity of the Scheme*, [Rsp to ExQ1 Q.1.4.1] is correct in a literal sense, but this solution comes at the cost of significant supplementary hardware and places an entirely unnecessary additional burden on an overstretched grid.

1.2.1 Integrated battery (Summary of REP1-111, p3.)

In a typical solar farm configuration, energy is provided by the PV array via its inverters (peak 400 MW).[2] The energy can charge the integrated battery and/or be fed directly to the grid.

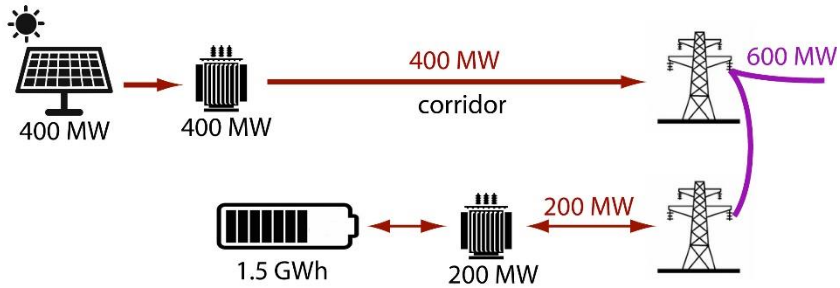
The AC-coupled battery has an export-import connection to the grid via transformers. A 200 MW grid capacity is sufficient to satisfy the day-normalised peak generation of the solar farm (see above).



During periods of low generation (e.g. winter) the battery can participate in grid support. A maximum charge/discharge time of 6 hr (1.5 GWh, 10%–90%, @200 MW) is appropriate for day-to-day balancing.

1.2.2 Remote battery

The location of a remote battery – a field adjacent to the solar farm, near a substation or distributed across multiple grid-connected facilities – does not affect the analysis.



In this configuration the transformer/switchgear in the PV pathway must handle 400 MW, as must the corridor cabling. An additional transformer is required for the battery facility. Grid capacity is increased threefold, as the infrastructure has to be able to support simultaneous maximum export from both sources.

Losses are introduced into the PV-to-battery pathway. As well as transmission line losses, transformers have <99% efficiency. There are at least five transformer stages in this pathway, based on the Applicant's proposal (LV→33kV→132kV→400kV→33kV→LV).

Moreover, unless the solar farm operator also owns the battery, there is no guarantee that all surplus solar production will be sold. Battery facility operators purchase electricity as and when the hourly wholesale price is most attractive.

[2] For clarity, numbers are rounded in this summary (in the Applicant's favour). Similarly, only real power is shown (a 200 MW transformer may need to be specified at 300 kVA).

1.2.3 The Applicant's position

Not known, beyond as stated above.
The Applicant did not respond substantively to the initial submission [REP1-111, p2–4]. Subsequent enquiry [REP6-028, p2] was also unproductive.

1.2.4 Summary opinion

The engineering, economic and operational arguments in favour in an integrated battery are overwhelming. No justification for the remote configuration can be identified.

1.3 Single Axis Tracking

The Applicant intends to use tracker (SAT) PV rather than conventional static panels (FSF). SAT exhibits higher annual yield per panel compared to FSF. This will be a 'first' for the UK.

The SoS will welcome the superior performance but will also wish to be reassured of the medium/long-term viability of this relatively untested and sophisticated technology.

1.3.1 SAT advantages

The Applicant has estimated the annual energy yield enhancement over FSF at, variously, 3% [Ans to ExQ1, Q.1.4.2], 12.5% [PVsyst analysis, Tech Note, 5.1.8b] and 15% [Applicant's Excel analysis, Tech Note, 5.1.7b]. PVWatts[3] analysis suggests 3% at North Yorkshire.

A secondary advantage of SAT is that it produces a flatter power profile than FSF (i.e. with a lower peak) despite the higher energy production.[4] The Applicant mentions this briefly in the Tech Note [5.1.4a, citing Need 6.5].[5] This reduces, to a certain degree, the power rating requirement for the farm's circuitry (inverters, transformers, etc).

1.3.2 SAT disadvantages

The defining feature of FSF solar – uniquely among energy technologies – is that it has no moving parts. Hence, 40 years of maintenance involves little more than a decent-sized lawn mower and an occasional contract with a window cleaner.
The higher installation cost of SAT is partly attributable to the central hinge design with bearings, and also to the numerous motors, sensors and sophisticated control circuitry – a centralised hub with cloud-based AI software to optimise and monitor performance.[6]

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[3] US National Renewable Energy Laboratory: publicly available simulation resource since 1999, https://pvwatts.nrel.gov/pvwatts.php v8.2.2.
[4] At/near the equator peak power is identical to FSF.
[5] It is not actually mentioned in Need, but it is nevertheless a valid observation in the Tech Note.
[6] Nextracker is a typical major producer: https://www.nextracker.com/resource-index/

Maintenance costs are difficult to predict for an emerging technology, but it would seem unlikely that many of the electric motors (30,700 in BOOM's design[7]) would survive for the full 40 years in Yorkshire's environment. This implies an inventory of spares and/or an assurance of form-and-fit replacement availability.

1.3.3 The Applicant's position

The applicant states that the FSF/SAT differential cost has fallen significantly in recent years, and [incorrectly] that at least eight solar NSIPs incorporate SAT [Tech Note, 5.1.1, and elsewhere]. SAT maximises the lifetime energy supplied to a 400 MW export connection.

The Applicant's parent[8] company [Ans to ExQ1, Q.1.4.2] and/or the Applicant itself [Ans to ExQ1, Q.1.5.1] has experience with SAT, having installed it at solar farm(s) in Australia.[9]

1.3.4 Summary opinion

On the basis of PVWatts analysis, SAT yield per panel is certainly significantly higher than FSF at lower latitudes (Madrid +66%, Riyadh +100%). But at 3% (or even 15%), the improvement over FSF in Yorkshire is marginal. Economically, the additional income will have to offset the higher installation cost and a 40-year maintenance regime before a financial advantage can be justified.

SAT is mostly (exclusively?) deployed in arid areas. The long-term effects of the damp and freezing winter of Yorkshire are unknown. Given the proven record of FSF in the UK, it seems foolhardy to sacrifice established reliability for a minimal potential return.

If SAT appeals to the SoS as a solution for the UK's energy future, he might wish to fund a pilot project from one the NZ grant budgets before rolling out this technology on a large scale.

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[7] 828,900 panels [4.1.5], 27 panels/motor [5.1.5] in Tech Note. Higher motor count in the future [6.1.5].

[8] More of a second cousin twice removed. And then divorced. [REP2-026, box on p4]

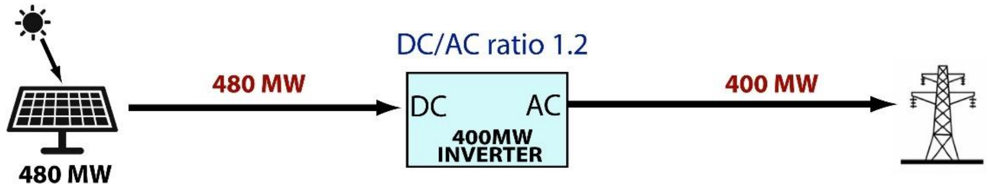
[9] The Applicant was asked about performance information for the existing SAT installations [REP1-111, p5]. There was no response.

1.4 Overplanting and DC/AC ratio

'Overplanting' is defined in EN-3 as the situation where installed capacity exceeds grid capacity. The EN-3 purpose is to mitigate panel degradation and thus maximise grid capacity utilisation.[10] 'Overplanting ratio' is not actually defined in EN-3, but it is frequently used in NSIP applications as the ratio of installed capacity to grid capacity.

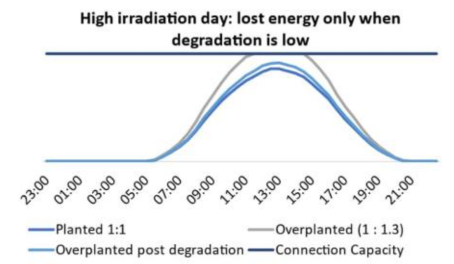
1.4.1 The East Yorkshire system

The Applicant has selected an overplanting ratio of 1.2 for East Yorkshire.



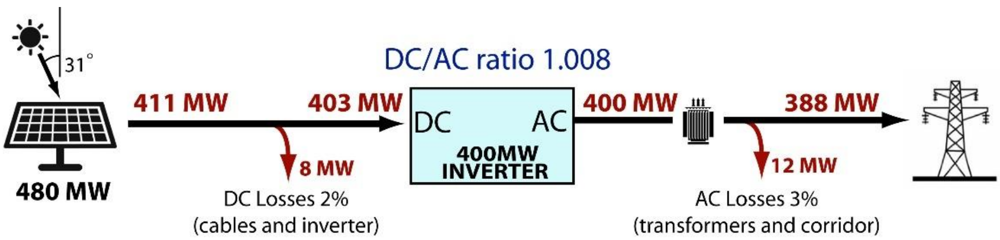
The Applicant explains how overplanting results in clipping within inverters to cap the output power when panel degradation is still low [Need, 6.6].

The ratio is better described as DC/AC ratio, as clipping depends specifically on the ratio of the maximum power offered at the DC input of the inverter to its rated (maximum) AC output.



Statement of Need © BOOM Power

For a domestic installation with a south-facing roof, the distinction is moot. For larger solar farms, the complete system must be considered.



For SAT-configured panels, peak output from 480 MW(p) will be 411 MW for 31° off-axis direct illumination (480*cos*(31)). DC and AC losses are estimated at 2 and 3% respectively.[11] For a 400 MW inverter the DC/AC ratio will be 1.008 with an export capacity of 388 MW.

Typical panels degrade by 1% in the first year, so clipping will have ceased by then.

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[10] Overplanting is also used in offshore wind farms. Equipment degradation here is not an issue. Submarine cabling is expensive, so the purpose is best economic use of the export capacity. See e.g. https://www.sciencedirect.com/science/article/abs/pii/S0306261923006906. Similarly, economic considerations are cited by installers for undersized inverters in rooftop installations.

[11] Inverter η<99%, panel cable ohmic loss 1%, two stages of transformers 1.5% ea, 8 km corridor 0.5% loss.

1.4.2 The Applicant's position

The question of peak DC power obtained from a 480 MW(p) SAT array was first raised at Deadline 2 [REP2-026, p8]. The value of 411 MW was suggested to preclude meaningful overplanting.

The Applicant responded [REP3-033] that PVsyst had been used to design the solar farm [PVsyst calculates annual energy not power] and drew attention to its Tech Note. The latter also addresses energy calculations, but with the explanation that 1.2 overplanting (120%) means that 20% additional panels will be used.

In response to the Applicant's statements at ISH2, the SAT peak power value problem was again raised [REP3-069], with a more detailed illustration of the angle of incident light issue.

The Applicant's response [REP4-029] again described PVsyst and directed attention to the Tech Note for an explanation of how overplanting works. The problem was briefly addressed by saying that the panels would *not* be horizontal at midday but directed at the sun using optical sensors. The Applicant did make a valid observation that the new bifacial panels collect some light from beneath rather than just incident sunlight (see below).

Despite a submission [REP5-025] pointing out that the optical sensor method to orientate the panel at the sun was a two-axis tracker feature – SAT panels would be horizontal – the Applicant's premature Closing Submission declined to address the 411 MW off-axis question further.

In its final contributions adjacent to this topic, the Applicant reverted to its initial position, consistent with the language of EN-3. *Overplanting is used to maximise the available grid connection capacity across the lifetime of the Scheme owing to the degradation effects …* [Ans to ExQ3, repeated for three questions].

1.4.3 Summary opinion

From a literal reading of EN-3, the Applicant correctly characterises the Scheme as using an overplanting ratio of 1.2. However, the described power clipping to mitigate panel degradation [Need] does not apply for this SAT design, because the DC/AC ratio of 1.0 ensures that clipping will never occur.

The analysis above assumes standard panels consistent with the Applicant's original submission. At Deadline 4 the Applicant introduced the possibility of using bifacial panels. Although more expensive, these generate higher (10%?) power for a given panel area and nameplate specification, by taking advantage of additional light reflected off the ground (albido). The Applicant did not go into detail ("see embedded diagram" was enigmatic), but any power increase for the available table area would benefit this or any scheme (SAT and FSF equally).

2. Regulatory Issues

As for all engineering advances, legislation lags technology.
On the evidence of recent Secretary of State Decision Letters, particularly that for Mallard Park, the present SoS is taking a proactive approach to amending shortcomings in the DCO. Some more-radical suggestions for the DCO might be appreciated.

2.1 Performance specification

Solar DCOs to date have specified an export capacity of "at least 50 MW." This is just the entry requirement for an NSIP application.
If an ExA approves a proposal for, say, 250 MW this should be reflected in the DCO. Otherwise, the SoS has no recourse if the solar farm builder subsequently constructs just 150 MW using the same land take.
As PV panel performance is likely to improve between the award of a DCO and the purchase of panels (typically around four years), this will not be an onerous restriction for the applicant. If unforeseen problems arise, the SoS is likely to be sympathetic, and it is a relatively trivial exercise to issue an Amended Order.

2.2 Decommissioning fund

Given the technical uncertainty and questionable longevity of novel technology, it is irresponsible to rely on funds becoming available when the farm ceases production – particularly if this is the result of a pronged period of reducing economic productivity.
The provision of a decommissioning fund in the DCO would assure adequate protection from unforeseen expense for local authorities (or other funding source).

2.3 Solar farm lifetime

Unlike nuclear power installations, there is no intrinsic lifetime to a solar farm. Components can be replaced/upgraded as the technology matures.
Furthermore, it is unreasonable to impose restrictions on future generations over the use of thousands of acres of (what will be) their land. National needs evolve – we are currently responding to a climate imperative – and authorities must be in a position to respond to the prevailing priorities.
A minimum assured span (at most 20 years) in the DCO should assure an applicant of adequate return on investment. Earlier termination could attract government compensation.

2.4 Construction/operation start times

Currently, the DCO requires that construction must start within five years. It imposes no limit on when full electricity production should be available.
This is consistent with non-NPS DCOs (similar to the ‘3 year’ stipulation in most LPA planning approvals) but is in stark conflict with the repeated government ambition for clean energy availability in the shortest possible time.
It must be possible to fashion a DCO that imposes a construction completion date, with the option for penalties/SoS sanction if this is not met. The involvement of the SoS’s department should not cease with the DCO award.

3. Technical Language and Confusion

To a reader with A Level Physics, the frustrating aspects of this application are the poor adherence to (or possibly comprehension of) scientific concepts and the unsatisfactory responses to technical enquiry.

3.1 Unusual science

There are some strange electrical observations, such as that batteries prevent 'burnout' of the grid infrastructure [Ans to ExA Q1, Q1.4.1] or that inverters regulate output by 'burning off' surplus electricity [Closing Sub]. Neither is correct.

Units are incorrectly expressed (*kWh/kWp/yr* for *kWh/yr/kWp* in ES Climate Change) or just meaningless (*480MW oversized AC peak*, twice).

Attention to scientific accuracy is woeful for a technical document:
The Scheme would generate enough electricity to power approximately 147,222 homes per annum [Planning Statement, 5.3.3].
It looks okay on a website, but how many red lines would it attract from a GCSE examiner?[12]

Of course, mistakes are bound to crop up in an application of this size. The problem is that this vein of quasi-science runs through the technical documentation. The ExA's attention has been drawn to multiple examples in the Statement of Need and Tech Note [REP2-026, p5–7; REP4-036].
The ExA might consider asking a local school Physics teacher for a second opinion.

3.2 Applicant's responses to questions

Rather than providing clarification and corrections, the Applicant's loquacious responses often avoided direct answers in favour addressing adjacent issues, (re)stating the obvious or ignoring a point altogether.
In the latter stages of the examination, the responses became increasingly difficult to fathom. The Applicant should be given the benefit of the doubt, but credulity is stretched:

The Tech Note informed us that PVsyst simulation provided the panel annual yield as 663.5 kWh, from which they calculated the total farm annual yield to be 549,760,279 kWh [4.1.5–6]. This simulation methodology was challenged [REP4-038, 2.1]. The Applicant explained that the Tech Note version was to assist the understanding of the ExA and respondents [REP5-021]. Apparently, we would have had difficulty understanding that PVsyst could compute the solar farm yield as 549,760,279 kWh.

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[12] Three. 1) "Homes per annum" is a unit of measure for house builders and TV licence inspectors; for power, it's just "homes." 2) Don't use six significant figures if it's approximate: "147,000". 3) Do not confuse power and energy. It won't power a single home over a year: there is no PV power at night. "*Over the course of one year, the Scheme will generate the same amount of energy as is consumed by 147,000 homes.*"

In its Closing Submission, the Applicant explained why SAT was selected for East Yorkshire but FSF for Fenwick, just ten miles away. Following the rigorous computational analysis that provided overwhelming support for SAT in the Statement of Need (and buttressed by the Tech Note), it was a surprise then to learn that the opposite conclusion had been reached for Fenwick. We are told that its fields are smaller and have rounded edges.

3.3 Tech Note Figure 2 – Energy generation based on 1990 weather data.

No sympathetic interpretation could be found for this contribution. The presented data can only be fabrication – for the simple reason that 1990 daily weather data does not exist.[13] It only raises further concerns about the Applicant's declared expertise.

1) An experienced user of meteorological data for solar PV simulation would be familiar with the parameters of the available meteorological datasets.

2) The Applicant used PVsyst for the design of both East Yorkshire and Fenwick.[14] PVsyst uses "1990" as the label for internally synthesised meteorological data [REP4-036, 2.1.4]. It uses this 'year' because it distinctly precedes real data. An experienced PVsyst user would be aware of this convention.[15]

3) In the context of a changing climate, did it not occur to the Applicant that presenting a graph based on data from 34 years ago (for no obvious reason) would raise an ExA eyebrow?

The tragedy is that this unsolicited graph contributed nothing to the debate: everyone knows that PV output fluctuates daily with the weather and that it is higher in summer than winter. The argument that *variability across seasons* demonstrates the necessity for overplanting [Tech Note, 4.1.6] is patently bonkers. The only possible reason for the graph's inclusion must have been to showcase some science-like rigour to bolster the Applicant's technical authority. This strategy appears to have backfired.

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[13] In the subsequent submission [REP5-021] *the Applicant is happy to explain to the ExA and Interested Parties, that it has included in its analysis,16 years of solar irradiation data from the European Joint Research Centre*. The 16 years covered by ECJRC PVGIS datasets are 2005 to 2020 inclusive.

[14] *The Applicant's experienced design team has used PVsyst to generate a professional indicative layout for the solar PV modules/panels across all the proposed fields* [REP5-021]. *PVsyst modelling was used for both the East Yorkshire Solar Farm and the Fenwick Solar Farm to test the optimal layout and type of panels* [REP6-023].

[15] The annual subscription to PVsyst is £625. A one-month trial copy can be downloaded for free.

3.4 Summary opinion

Leaving aside the disappointing examination responses and questionable integrity, the major concern is the apparently poor appreciation of the electrical issues of solar farm design and familiarity with simulation technology.
This was most evident in the unproductive examination discourse over SAT illumination angle [1.4.2 above]. There may be valid engineering arguments to support the Applicant's position, but we didn't get there. We stumbled at school Physics.

One is left with the impression that *the Applicant's experienced design team* for a multi-hundred-million-pound electrical installation might not include an electrical engineer – or possibly even an A Level Physics certificate.

4. Summary Conclusion

The East Yorkshire application places much weight on previous solar farm DCO decisions. This is misplaced. ’Case law’ is for the courts, not NSIP examinations. Each application is judged on its merits.

Similarly, the Applicant’s ‘check box’ approach to legislative directives is overly simplistic: Does EN-1 require a battery? No. Conclusion: the application is compliant.
But EN-1 is nuanced: its holistic stance encourages a battery. The Applicant should be obliged to explain why a battery is considered unnecessary in this particular case.

The evasiveness of the examination responses has been particularly frustrating. Similar economy with the actualité has been noted for the land-take calculations. This only casts further doubt on the technical claims and, by extension, on the application in general.

Concerning the principal electrical issues:

1) An AC-coupled, integrated battery is expected for a Net Zero solar farm. Without it, commercial viability is uncertain and the nation’s energy security is weakened. Subsequent addition of the missing battery compound is impractical, from both engineering and economic perspectives.

2) At 54°N, the marginal yield advantage of SAT is outweighed by the proven reliability and zero maintenance of FSF.

3) Strictly speaking, the overplanting ratio of 1.2 is accurate (if disappointing). Because of the SAT configuration, the DC/AC ratio will be 1.0, so no overplanting benefit will be obtained.

The technical content of this proposal and the examination responses give the disturbing impression that this sophisticated electrical project may have been designed by someone other than an electrical engineer.

BOOM and its investors will be taking a monumental risk if this proposal is approved.

Of the solar NSIP applications in the Inspectorate’s inbox, this is probably the least satisfactory from the engineering standpoint.
It fails to satisfy the objectives of the National Policy Statements.

Planning Act 2008: s104(7)
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