Comparative analysis of PEG® versus Single Axis Tracker solar mounting approaches in NSW, Australia

Completed by Constructive Energy Pty Ltd

June 2024

Contents

1. Executive Summary

Recent experience with design and construction of both PEG EW and SAT solar mounting systems has been used to model a test case powerplant in Central NSW for analysis. This enabled reflection on both PEG and SAT approaches for a feasible powerplant based on real-world figures.

Our comparison revealed that PEG EW resulted in a productivity cost of $605 per MWh versus $636 for SAT to create the equivalent annual volume of electricity in the grid. This compared a PEG EW project that was 35% higher in DC capacity than the SAT system it was compared to. Costs considered included supply and installation associated with the powerplant only – essentially from the panels to the Medium Voltage Power Station.

It is noted that projects analysed were in New South Wales, Australia around 32.5^{o} South – a region sometimes regarded as 'contested' in the choice between PEG and SAT mounting systems. In addition to an apparent financial advantage, the report points to a number of other considerations that may be deciding factors in favour of the simple and compact PEG mounting approach.

2. Background

From the earliest days of solar PV panel deployment there has been an argument to mechanically track the path of the sun to optimise energy yield. However, as the price of panels has fallen, the relative benefit of increased production has been offset by increased capital and operation expenditure compared to fixed mount systems.

In the Australian context, two fundamental approaches have emerged to dominate the utility scale solar array sector; single axis tracking (SAT) and PEG east-west fixed mount (PEG EW).

Constructive Energy has been involved in the development and delivery of both single-axis tracking and PEG EW at around the 5MW scale, known in Australia as 'Mid-scale' because 5MW (AC) represents a compliance threshold in within the National Energy Market rules. This report details our experience with four current projects and provides a comparison of each approach, specifically around those aspects of capital expenditure that are directly comparable.

3. Projects Overview

Projects have been de-identified for reasons of Commercial Confidence however they are in regional NSW, relatively close to the same latitude of 35.5^{o}S, reasonably similar in altitude and with comparable weather conditions. All sites are on gently sloping, previously cleared agricultural land. The SAT project is under construction at the time of writing. In order to create a valid comparison, CE produced and modelled a theoretical test case powerplant based on the as-built and budgeted costs drawn from three other PEG projects.

As a check to this methodology, an Australian-based PEG specialist also provided a pricing estimate for the same site as the SAT system.

Each project has taken a central inverter approach, and is connected in the Essential Energy Distribution Network, following identical connection approval processes. The projects have equivalent inverter capacity (4.4MW AC) and network connection approvals of around 3.75MW AC however the projects are different DC sizes. The tracking system is 5.005 MW DC whereas the PEG® system is currently specified at 7.833 MW DC.

Equipment Overview	SAT Array	PEG®EW Array
Inverter AC Capacity	4.4	4.4
Interconnection AC Limit	3.75	3.75
MW DC	5.005	6.850

Table 1. High-level project parameters

Capital expense for the SAT is based on contracted values. For the PEG® EW system, costing is based on a projected budget however this has been informed by the very recent experience of Constructive Energy in delivering an equivalent array and also pricing provided by an Australian PEG specialist installer.

The single axis tracking array has been designed with a central inverter as a DC Coupled ‘battery ready’ system. The project has suffered relatively extensive network augmentation requirements, the ongoing impacts of time delays, supply constraints and a high level of regulatory oversight.

The test case PEG EW array and SAT array both have a similar DC-coupled ‘battery ready’ architecture and central inverter(s) design.

It should be noted that both the arrays and the project budgets are handled by each project proponent differently. For this reason, a direct comparison is not a valid approach as we are not ‘comparing apples with apples’. In the section below we outline the methodology undertaken to find an equivalent measure across both systems.

4. Methodology

Constructive Energy has developed an excel-based 'flow model' designed to simulate the performance of an individual solar array, utilising PVSyst data as its primary input. The model enables adjustment of various parameters, such as string configurations, inverter efficiency, inverter set points, network constraints, and financial factors necessary for generating cash flow projections, Net Present Values, and other relevant metrics.

In order to make meaningful comparison, the two projects were harmonised based on the export energy seen by the grid. In other words, CE has taken the approach of comparing PEG® Vs Tracker based on what the powerplant is capable of generating, not system size or configuration. Both projects flow models were considered with identical grid connection and inverter parameters.

The base model for the PEG EW system was originally smaller than the SAT system so this was virtually expanded to reach the equivalent generation of the SAT system, modelled to deliver 9,626 MWh to the grid. In other words, the PEG® system test case model was varied in DC scale (essentially by modifying the string count) until the grid output became equivalent. The Australian PEG installer also kindly completed a preliminary design to match the SAT PVSyst file for the same location and confirmed our modelling (within 0.6%).

The cost of solar panels significantly influences Capex and is determined by factors such as type and timing of purchase. To standardise this across models, the price of panels in the PEG® system was adjusted to reflect the actual purchase price of panels for the Tracking system. Similarly, central inverter/transformer prices vary among vendors and are susceptible to exchange rate fluctuations. Given the considerable disparities between projects, these prices have been standardised as well.

A process was undertaken to review inclusions/exclusions for the budgets which were framed differently. Because of the way packages were bundled, CE did not have the same level of full, individual line item, transparency on the tracking project budget as for the PEG® project. To ensure direct comparison was relevant, CE matched PEG and SAT systems across the following common labels.

- DC Project Management – equal for each
- Clearing of land – reduced for PEG by 40% to account for reduced area and intensity of earthworks
- Mounting structure
- PV Mounting System Installation
- Panel Supply
- Panel installation
- Inverter Supply
- Site fencing
- Site security
- LV/HV Equipment Supply, Install and Testing (Grid Protection, RMU and MV Inverter TX Skid Install)
- Supply and Install HV Cabling and Connections
- DC Submains - including Submain Isolators etc.
- Civil -UG pathways AC / DC
- Tray Pathways
- Testing and Commissioning and Inspections (including As Built Docs etc.)

CE has sought to remove items that were unique to each project and to create bundled, equivalent line items. This has the impact of delineating the capex budget for an imaginary site looking specifically at the DC array elements. This results in a comparison of the powerplant costs only (up to the Point of Connection), not full project delivery costs.

Further commentary is provided in Discussion below.

5. Results

In order to harmonise the powerplants for analysis, the PEG® model was adjusted until the equivalent annual production was reached.

	DC Capacity (MW)	Annual Production (MWh)
Tracker	5,046	9,626
PEG®	6,850	9,626

Table 2. Modelled result for production equivalency

The above table indicates that the PEG® system is effectively 'oversized' by ~36% relative to the tracker system in order to export the equivalent 9,626 MWh to the network. However, this results in a 'spill' of 935 MWh or ~10% which is 'clipped' by the instantaneous inverter limit during annual peak solar periods. For comparison, the spill on the tracker system is approximately 450kWh or 5% in year 1.

Furthermore, the full AC capacity of the PEG® array at 6,850 MW is 10,561 MWh, however a battery would be required to harvest this energy. Also, a smaller PEG® array of 6,247 MW (25% larger than the single-axis tracking system) would theoretically produce 9,626 MWh with less clipping but would result in a different generation shape to the SAT system. These are important insights and design considerations that relate to the specific context and objectives of any particular installation.

Anecdotally this aligns with our experience over several feasibility studies; that an EW PEG® system needs to be *about* 30% 'oversized' to provide equivalent generation to a single axis tracking system. This equivalency includes the generation 'shape' which peaks earlier and remains flatter across the day for both PEG EW and SAT systems compared to a north-fixed, classic solar bell curve. As batteries become increasingly cost-effective the equivalency of load shape may not be as important which would enable increased harvest/less clipping and thus, reduced % oversizing.

Budget analysis revealed the following groupings and aggregated costings for the arrays.

Aggregated Items	SAT Array (AUD)	PEG®EW Array (AUD)
DC Hardware (panels, substructure, electricals, inverter)	$3,935,000	$4,044,000
PV System Installation (Including civils, site prep)	$2,191,000	$1,983,000
Total	$6,126,000	$5,828,000
Cost per Watt	$1.21	$0.85

Table 3. High-level costings

There are several qualifiers to the findings including:

- No two sites are the same and each had different design teams and proponent objectives
- Broad assumptions have been made regarding the capacity of line items to scale linearly or otherwise
- The SAT costings relate to a single specific project. The PEG costings are inferred from other projects.

However the central outcome is clear; in this circumstance PEG® mounting is significantly less costly than single axis tracking on a per-watt installed basis – approximately 30% less. However, to reach the equivalent electrical energy production of a single axis tracking system, the array size needs to be expanded.

If we consider that the Aggregated Items in the table above represent the cost of building a powerplant to generate 9,626 MWh of electricity in year 1, then a simple metric of cost/MWh annually emerges.

Performance indicator	SAT Array (AUD)	PEG®EW Array (AUD)
Annual grid export	9,626 MWh	9,626 MWh
Powerplant Capex (NB not full project Capex)	$6.126 million	$5.828 million
Capex per MWh produced	$636 /MWh	$605 /MWh

Table 4. Powerplant Cost per MWh Annual Production

Of further interest is the division between installation and hardware costs for each array calculated by simple apportioning of the $/W result in the same ratio as Capex above.

Aggregated Items	SAT Array (AUD)	PEG®EW Array (AUD)
DC Hardware (panels, substructure, electricals, inverter)	64% or 0.78 $/W	66% or 0.56 $/W
PV System Installation (Including civils, site prep)	36% or 0.43 $/W	34% or 0.29 $/W
Cost per Watt	$1.21	$0.85

Table 5. Division of costs

Again, it should be noted that this analysis represents an attempt to harmonise two distinct technologies and providers and the division indicated above is determined by 'what's in or out'. Each supplier will have a slightly different view on this. It was interesting to note the similar ratios for hardware to installation for both arrays.

Constructive Energy had imagined that factors such as increased fencing length and more extensive earthworks (e.g. levelling and trenching) associated with trackers would have made this a significantly higher percentage than in the PEG® array, but this is offset through reduced panel purchase. On the other hand, it appears that while there are more panels and rods/foundations required to create the same amount of energy with PEG® compared to trackers, it is more cost-effective to install them.

The impact of changes in panel pricing was modelled by altering the figure for cost per watt and noting the corresponding Capex. The following chart indicates the trend that emerged.

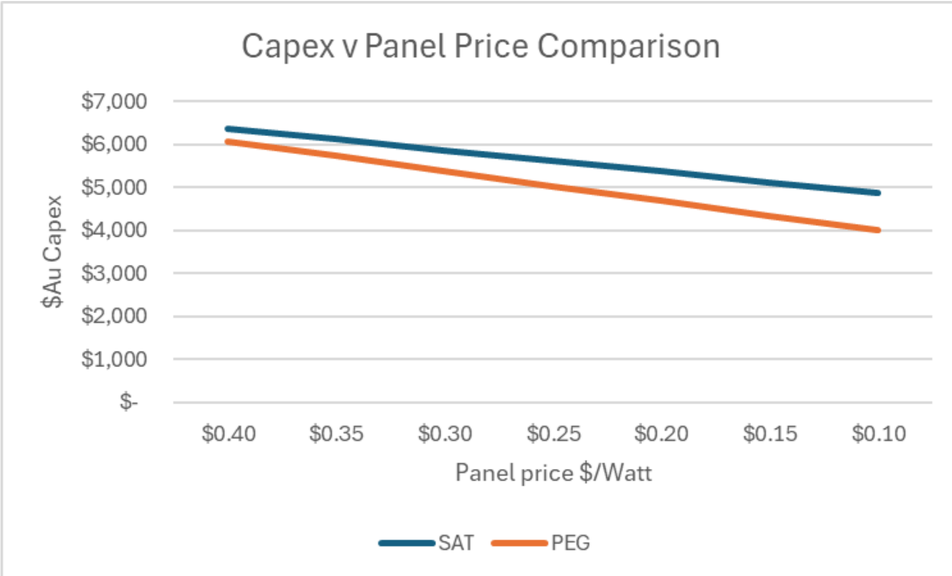

Figure 1. Relative impact of changes in panel pricing

As indicated above, a fall in panel prices disproportionately improves the powerplant cost for the PEG approach. This stands to reason given the reduced material requirement for PEG representing a smaller proportion of cost than the engineered tracking structures.

Finally, in the case of most solar arrays in Australia space is not constrained and productivity per Ha becomes a lower-tier metric for project proponents. None-the-less, we have compared the 'as-built' footprint of the SAT array and compared that to the design provided by the experienced Australian PEG specialist installer. The project footprint includes the fenced area which requires a 10m fire management zone external to all edge panels.

	Project Footprint (Ha)	Year 1 production (MWh)	Productivity
SAT Array	9.50	9,626	1,013 MWh/Ha
PEG Array	4.57	9,626	2,106 MWh/Ha

Results show that in this context the PEG system is approximately twice as productive per unit area than the SAT system. It should be noted that the analysis in this report includes an adjustment to Capex for reduced area disturbance, civil works, fencing, etc. It does not include the less tangible impacts of reduced land disturbance such as biodiversity, soil integrity and alternative land use.

6. Discussion

Central to this report is consideration of the relative benefits of PEG® versus SAT arrays and, specifically, the financial picture that emerges from each.

This analysis compared an actual SAT project with a projected PEG array of equivalent production within the same general area and drew on real, market-tested pricing. While we were unable to obtain the same level of granularity across both projects, we are confident that the results offer a reliable and pragmatic comparison. That is, while we may discover some minor items that could be 'in or out' of each capex budget aggregation, these would be small compared to the main items - inverter, panels, mounting structure and installation.

Site design and land-related impacts

Of bigger potential impact are key decisions that would be made in relation to each site and project. For example, inverter sizing, layout and civil earthworks and the addition of BESS which could significantly reduce inverter clipping. These are factors considered in the detailed design stage and, in our experience, no two electrical engineers will think the same way!

The point of this is to say that consideration of whether to go for SAT or PEG® EW may be impacted more by site considerations than the economics presented in this report. Factors to consider include:

- Land area available – PEG® systems generate more energy per hectare/acre
- Terrain – tracking systems on sloping land tend to require more civil earthworks
- Visual impact – PEG® systems sit lower in the landscape than tracking systems
- On-going land use – each approach provides different opportunities and limitations
- Latitude - distance from the equator impacts the relative yield of PEG, SAT and fixed arrays.
- Cost of land – for capex and/or opportunity cost.
- Reduced material use (eg steel) and associated CO_2 emissions of PEG EW versus trackers
- Local labour and skill capacity to meet construction tasks and schedule
- Latent conditions - foundations of PEG EW tend to be shallower than trackers
- Construction delay risk for SAT tends to be higher than PEG EW based on timelines observed for both projects
- Construction process/complexity - PEG® is simpler, reducing risk.

Our analysis found the capex for the DC component of the arrays to be broadly equivalent when designed to deliver the same annual output to the grid. Given this, a single factor in the above list may sway the decision to proceed with PEG® EW or SAT.

Operation and Maintenance

While Capex is an important determinant for investment, Opex is also crucial in limiting financial returns over time. Although not in the scope of this report to evaluate cash-flows based on each project, as a general rule, the more simple a system is and the less moving parts it has, the more reliable and easy it will be to maintain.

Panel cleanliness is also a factor which can result in reduced yield although in most cases the reduction is a few percent, from a dust storm for example, and often the cost of cleaning is not justified by the additional yield. Salty or very dusty environments may justify regular cleaning and in the case of E-W fixed arrays, mechanized/robotic solutions are emerging. SAT system panels are readily cleaned by human teams – at a cost.

Panel longevity may be a factor that separates PEW EW-W fixed and SAT arrays over time as there is some thinking to suggest that the reduced direct exposure to sunlight allows panels to cool and rest for longer periods than a tracking panel which 'works hard' all day.

Other factors outside the scope of this report include electrical maintenance, ease of repair/replacement, legislative compliance and landscape maintenance.

Market dynamics

The PEG® EW system is more significantly affected by changes in panel cost and efficiency due to its larger number of panels. In other words, a 10 percent decrease in panel price would have a more favorable impact on reducing Capex for the PEG® EW system compared to the tracking system.

As battery prices decrease and energy storage systems become more affordable, the commercial viability of the PEG® system will improve over time. This is because it becomes increasingly cost-effective to shift energy generation from morning and evening peaks, consequently reducing the higher percentage of clipping typically associated with a PEG® array compared to a tracking array.

Energy market pricing may also have a bearing on the effectiveness of E-W tracking approaches as the morning and evening consumption peaks tend to correspond with higher prices.

Finally, geopolitical factors may play a role in approach selection too. The simpler PEG mounting components can be readily manufactured on-shore and reduced material quantities reduces exposure to commodity and component markets.

7. Findings

Comparing the core powerplant components, this study finds that the installed cost per watt for the PEG®-mount solar array is approximately 30% less than for the SAT. However, in order to match the grid generation potential of the tracking array, the PEG® system needs to be ~36% larger than the SAT in terms of DC peak capacity. Overall, this results in an array that is approximately 5% lower in Capex than the SAT for an equivalent generation.

Notwithstanding the impact of operation and maintenance costs on overall project performance, in this case study we find that capital costs of generating energy via a PEG® EW mount array versus a single axis tracking array are lower. While hardware : installation ratios are similar in both approaches, the material and installation efficiency of the lighter PEG structure wins out overall.

Falling panel prices will be of greater advantage to PEG systems than trackers because of the proportionally larger impact this has on overall powerplant Capex. Similarly, as battery prices fall, this has greater incremental benefit in a PEG approach because it reduces clipping, enabling reduced ‘over spec’ to gain equivalent production in shape and volume to a SAT system.