Georgia Power Solar array (approx. 1MW) at UGA: Factsheet by UEM

Location, area, and connection

The solar array is located next to the UGA Club Sports complex, and the fenced area covers (near enough) eight acres of land (348,041ft^2 by Google Maps). The array and associated equipment is owned by Georgia Power and is off-limits to others (including for safety reasons). With no overhead transmission wires visible, it is assumed that the grid connection is via

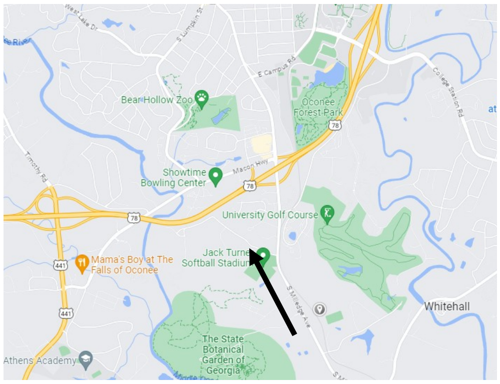

Fig1: location of solar array (Credit: Google Maps)

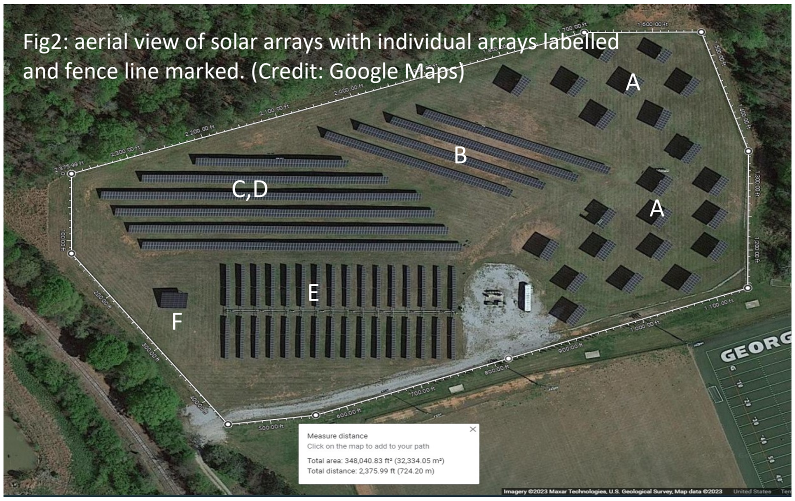

Fig2: aerial view of solar arrays with individual arrays labelled and fence line marked. (Credit: Google Maps)

Arrays B, C, D, and F: fixed axis

Fixed-axis arrays are the most basic type of array in general and on this site. Densely packed in rows, they effectively use the available space and have no moving parts to maintain or control. Typically (and as it appears to be in this case the south-facing arrays C and D), the tilt angle is equal to the degrees of latitude at the solar array's location, so that the photo-voltaic (PV) modules are pointing towards the annual average sun angle[2] at solar noon[3]. These fixed arrays produce significantly less electrical energy in the morning, late afternoon/early evening, or in the winter compared to those based on trackers, due the difference between their tilt and the sun angle reducing the effective solar intensity on the panels, but are significantly less costly to install and maintain and are more reliable than systems with solar trackers. Arrays C and D appear to be indistinct, but differ in terms of their electrical inverters: one has a 1.3 AC to DC ratio[4], the other 1.5.

Fig 3. South-facing Arrays C and D (foreground) and south-west facing Array B (background). Arrays C and D generate more energy over an average day than B, but B generates more during periods of peak demand (early evening). The small shadows in this image indicate that the photograph was taken near to solar noon; in the early morning, the shadow would extend back towards, and even onto, the row behind.

Fig 4. Along-row view of Array C/D demonstrating tightly-packed rows (high Ground Coverage Ratio, GCR) with minimal space require between rows to prevent mutual-shading. The PV supporting structures are clearly seen to be rigid, with no mechanical equipment. The resulting lower overall weight allows for simpler siting in the ground. Electrical equipment connecting module rows into the larger array are placed under the module rows, in shadow, to keep them as cool as possible for the sake of efficiency.

While south-facing arrays generate more energy overall on the average day the peak energy production (at noon) does not coincide with peak demand (in early to mid evening). By orienting Array B towards the south-west (Figure 2), there is greater coincidence between peaks in its production and in general demand, which in turn reduces the need for battery storage[4]. Array F is a much smaller fixed-axis solar module, facing south, which appears to have a dedicated battery unit to investigate the effectiveness of PV-battery synergy for south-facing arrays.

Fig 5. View of electrical equipment (presumably batteries) under the shading of Array F, fixed axis, facing south.

Arrays E: Single-axis Solar Tracker (SAST)-mounted PV modules

One step-up in technical complexity from the fixed-angle arrays, SAST arrays consist in long rows of modules mounted on a single, long rotational axis. At low and moderate latitudes, such as ours in Georgia, the axis of an SAST will typically run north-south, allowing the modules to be rotated continuously from a high angle east facing (in the morning), through a zero angle facing upwards (at solar noon), through to a high angle facing west (in the evening), before returning to the east-facing position for dawn the next day. While SAST arrays cannot typically be tilted towards the sun's zenith angle unless it is located at a very low latitude, the rows can be tilted slightly to favor PV generation at noon (as they are here). This daily tracking allows for enhanced generation both in the morning and evening (compared to fixed, south-facing arrays) without significant loss of generation at solar noon.

Fig 6: SAST- diagonal view. Small shadows directly beneath the modules, along with a very low rotational angle (modules pointing almost directly upwards) indicate the photograph was taken close to solar noon. Wider spacing between rows (compared to fixed-angle arrays) is visible. In early morning or late evening, modules will be rotated at steep angles, casting shadows up to the adjacent rows.

Fig 7: SAST– axial view. The pentagon-shape is the end of the rotational arm onto which the modules are fixed and which forms the axis of rotation. The hydraulics that rotate the module are visible, sticking out to the right, under the module. The array above/behind is the south-facing fixed array, the array to the right is the south-east facing array.

By adopting steeper angles in the morning and evening, the rows of modules cast longer shadows, and this mutual shading between rows limits the GCR before the close spacing becomes counter-productive. The mechanical system has various costs which need to be considered when evaluating the best array option: the direct financial cost of the mechanical equipment and its installation, the direct financial and operational cost of its maintenance, the indirect cost of additional structural support for its mounting in the ground, and a small but significant energy cost in rotating the module rows. Anecdotally, despite these added costs, such SAST arrays are preferred to fixed arrays, with the improved overall generation worth the additional extra cost; however, this will depend on the available land. SAST arrays are typically only viable when ground-mounted.

Fig 8: Signage on electrical box outside the fence line, indicating the presence of underground electrical wires which, in the absence of overhead wires, presumably provide the connection between the array and the grid.

Array A: Dual-axis solar tracker (DAST)-mounted PV modules

The most technically advanced PV arrays are those which are mounted on a single, rotating, vertical axis (that continuously varies the “azimuthal angle”, tracking the sun’s relative motion east-to-west during the day) and also have a tilting mechanism (that allows a module’s tilt angle to vary from a high angle in the morning, through to a relatively flat angle at solar noon, back to a high angle again at the evening when the sun returns to a “low” position in the sky). As well as maximizing solar output per unit area of module for each hour of the day (and to a greater extent than the SAST), DAST-mounted modules also boost generation across seasons, as the rotation and tilt can be tuned to lower angles in winter and higher angles in summer, to track the sun’s movement more closely.

However, DAST systems have drawbacks, both in terms of cost and operations and in scaling challenges. The second degree of motion is significantly more complex to achieve than the single degree of SASTs, requiring substantially more upfront investment and ongoing maintenance. Their reliability is also questionable: for example, two of the 22 tracking units in Array A were out of action at the time of writing. In terms of scaling, DAST modules have to be widely spaced (figures 2 and 9) to avoid mutual-shading as they cast large shadows across a half-circle over the day. (Large module sizes are necessary for the tracker mountings to be cost-effective, resulting in large shadows). The modules’ large size also require that they be mounted high, exacerbating the shading and spacing issue, and complicating maintenance. Anecdotally, DASTs are rarely the preferred technology, and typically only where space is limited such that a single, large, module is the optimum choice.

Fig 9: DAST—rear view. These modules are significantly larger in size, higher mounted, and further spaced, than SAST or fixed-angle trackers. The unit to the right is clearly at a flat angle, not tilted towards the solar zenith, indicating it has reverted to its default position due to a failure in its tracking system. DAST systems are most effective at high latitudes (where sun angle varies most) and where the availability space determines that a single, large, module is preferable to a longer row array.

Notes.

1. If more electrical energy is desired in summer months at the expense of winter months, then the array can be mounted at a flatter angle (pointing “higher” in the sky) to point more towards the sun’s zenith in summer months, and consequently away from the sun’s zenith in winter. Conversely, a steeper angle will point more towards the sun in winter months at the expense of summer. By orienting the whole array towards the east or (in Array B’s case) the west will favor energy production in the morning and the evening respectively, at the expense of the other.
2. Solar noon is the time at which the sun appears at its zenith (highest angle) at that given longitude—this can vary from the official/civic noon depending on where the location is across the east-west length of that time zone, and if the jurisdiction is observing daylight saving adjustments.
3. The difference between arrays C and D is in terms of their inverters, not the PV panels themselves. One of them has a 1.3 DC to AC ratio (that is, its AC inverter is rated at 30% less electrical power than the maximum rated DC output of the array) and the other, a ratio of 1.5. While this may seem wasteful, it is important to note that solar panels very rarely, if ever, produce their maximum output, given the daily and seasonally varying solar intensity, and the fact that electrical efficiency decreases with increasing temperature, which is tightly-correlated with solar intensity. Therefore, a smaller inverter (and thus a higher DC to AC ratio) is often more cost effective as relatively low amounts of electrical energy is lost (or, “clipped”) during the brief periods of maximum output.
4. Although batteries can play a valuable part in bridging the time-gap between generation and demand they have several shortcomings: high capital cost, very high ecological and human cost (in extraction of raw materials and in their disposal), supply chain limitations, energy losses in charging and discharging, limited number of charging-discharging cycles in their life-time, high O&M costs, and social/geopolitical concerns with the sourcing of their raw materials.