Solar Farm 3 (On Campus)

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Abstract: A third on-campus solar farm could more than double campus solar electricity and yield considerable cost savings.

Introduction

Once Solar Farm 2 (10 MW) is completed, our campus will have around 16 MW of solar farm capacity, putting it in the lead (along with UC Davis) amongst US universities for on-campus solar farm capacity. While that is a considerable achievement, only about 6% of campus electricity use will be provided by solar. Here we explore the possibility of a third on-campus solar farm to significantly increase the percentage of solar electricity.

The main economic advantage of on-campus solar electricity compared to grid electricity is the avoidance of delivery costs, which are substantial. For example, Solar Farm 2 will provide electricity for 20 years at a fixed price of $46/MWh, avoiding the purchase of grid electricity at a price of about $32/MWh (supply)[1] + $33/MWh (delivery) = $65/MWh. The savings from solar electricity vs. grid electricity are thus about $19/MWh, nearly a third of the price of grid electricity. The savings will be even greater as the price of grid electricity inflates over the next 20 years.

Here we consider a third solar farm of capacity 20 - 40 MW, which is large enough to more than double the capacity of on-campus solar electricity. Due to economies of scale, a solar farm of this size should be able to provide electricity at a lower cost than that of Solar Farm 2; we use $40/MWh as an estimate. A solar farm of 20 MW capacity would require about 100 acres, and could fit comfortably on the land lying between Solar Farms 1 and 2 (see figure).

Another option for a third solar farm is off campus. However, an off-campus solar farm does not avoid the cost of delivery. The economics work out if the supply cost of solar electricity is less than the supply cost of grid electricity. While that is potentially possible for a utility-scale solar farm in Illinois, an on-campus solar farm has a greater upside potential, as we will show.

Solar Farm 3

We begin our study by confirming the results of the UIUC Campus Green Power Purchase Study, done by Affiliated Engineers, Inc. (AEI). We are able to reproduce all the results of Table 5 and 6, which are the main results of the study. This gives us confidence in our input data and calculations.[2]

With the addition of a third solar farm on campus, there will inevitably be times when campus electricity generation (solar + Abbott Power Plant) exceeds campus electricity demand. This typically occurs in the winter, when Abbott is cogenerating electricity along with steam for campus heating. In this situation, one can choose to either reduce Abbott electricity production, or to sell the excess electricity to the grid, collecting the real-time (supply) price of electricity. We chose the latter option in our study. Upon further study, one may find that

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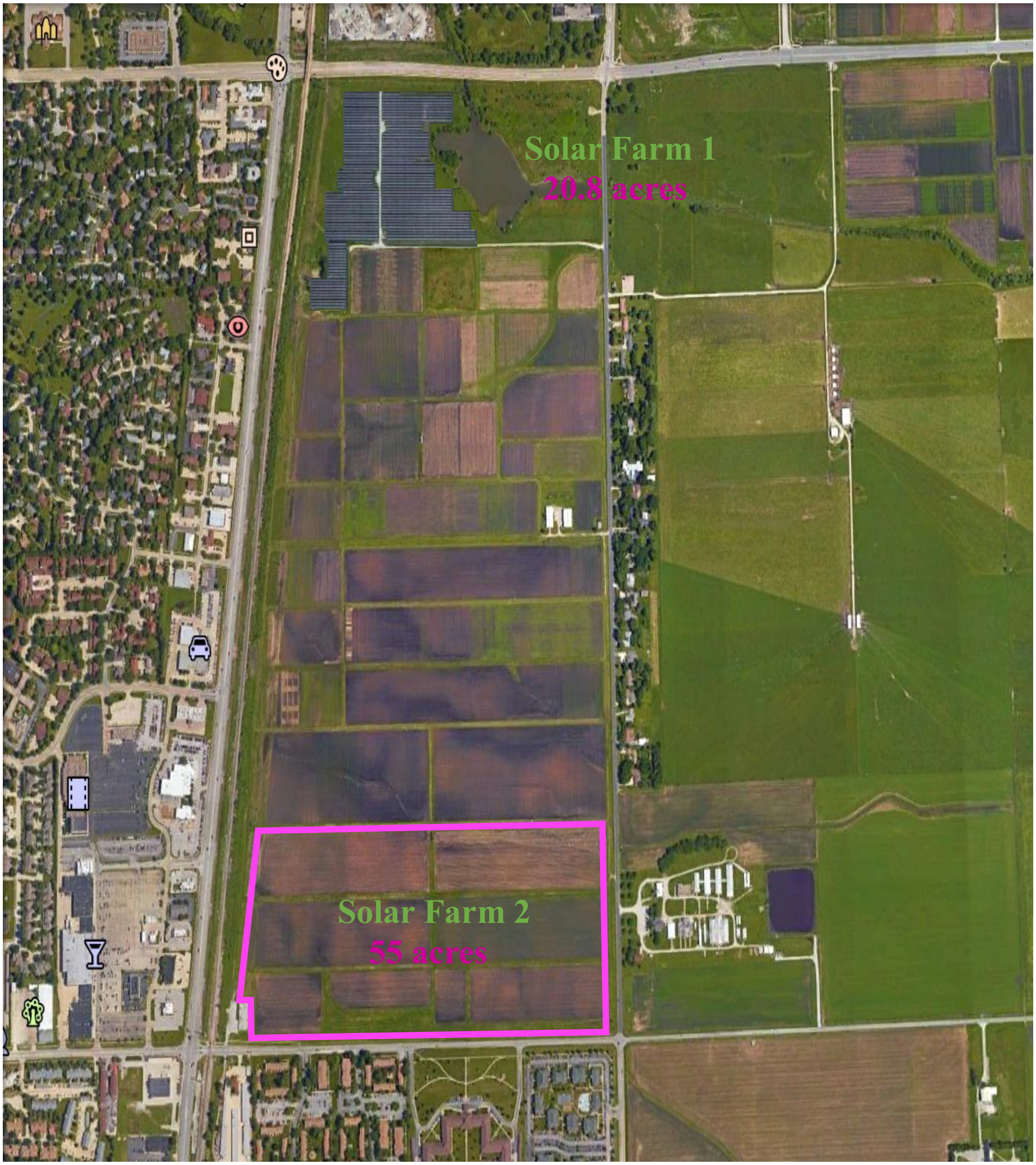
[1] See L. Spychalla and S. Willenbrock, "Single-Axis Tracker" (March 2019).

[2] To further establish our credibility, we noticed a few percent discrepancy between our results for Abbott Power Plant electricity generation and the results of AEI. It turned out that AEI had used slightly different input data, and this accounted for the discrepancy. Thanks to Mike Marquissee for tracking down the source of the discrepancy.



Solar Farm 1
20.8 acres
Solar Farm 2
55 acres

it is more cost-effective at times to reduce Abbott electricity production than to sell excess electricity to the grid.[3]

As with the AEI study, we begin with FY17 data for campus electricity generation, purchasing, and usage. We then add Solar Farms 2 (10 MW) and 3 (10 - 60 MW), both as single-axis tracking arrays.[4] Whenever possible, we replace grid electricity with solar electricity, which is always financially favorable. Whenever solar electricity plus Abbott electricity exceeds campus demand, we sell the solar electricity to the grid and collect the (supply) price of electricity. This is always financially unfavorable.

Results are shown in the upper left-hand portion of the table below, where we list both the annual savings and the savings per unit of electricity. Once completed, Solar Farm 2 will yield an annual savings of $306,912, corresponding to $17.02/MWh. Solar Farm 3 (20 MW) yields additional annual savings of $494,414, corresponding to $16.12/MWh. Even greater annual savings result from Solar Farm 3 (40 MW): $679,508, corresponding to $11.08/MWh. The savings per unit of electricity are not as great for Solar Farm 3 (40 MW) as for Solar Farm 3 (20 MW) because a larger percentage of electricity generated must be exported (at a loss). For this same reason, Solar Farm 3 (60 MW) does not produce significantly more annual savings than Solar Farm 3 (40 MW).

We show the same results in the upper right-hand portion of the table, but subtracting a constant load of 10 MW from campus demand to simulate the end of Blue Waters operation. This results in more exported electricity, and hence less favorable economics for on-campus solar electricity. The maximum annual savings, $240,575, results from Solar Farm 3 (20 MW); larger capacity does not increase annual savings.

We are currently in Year 4 of a 10 year PPA with a local wind farm that requires us to purchase their electricity at a fixed price. Once that agreement is over, we will have the flexibility to replace more of our purchased electricity with solar electricity. This improves the economics of Solar Farm 3. The bottom half of the table shows the same results as the upper half, but without the wind PPA. Both the annual savings and the savings per unit of energy are increased for a given capacity of Solar Farm 3.

With Blue Waters With Wind

	Net Savings ($)	Net Savings per MWh ($/MWh)
Wind	-345885.41	-14.42
Solar II	306912.36	17.02
Solar III 10	289844.40	18.90
Solar III 20	494414.73	16.12
Solar III 40	679508.28	11.08
Solar III 60	681251.07	7.40

Without Blue Waters With Wind

	Net Savings ($)	Net Savings per MWh ($/MWh)
Wind	-505956.61	-21.09
Solar II	205230.68	11.38
Solar III 10	164115.40	10.70
Solar III 20	240575.01	7.84
Solar III 40	234028.72	3.81
Solar III 60	117631.68	1.28

With Blue Waters Without Wind

	Net Savings ($)	Net Savings per MWh ($/MWh)
Solar II	324567.91	18.00
Solar III 10	313202.04	20.42
Solar III 20	542411.82	17.68
Solar III 40	771048.05	12.57
Solar III 60	801471.13	8.71

Without Blue Waters Without Wind

	Net Savings ($)	Net Savings per MWh ($/MWh)
Solar II	238755.74	13.24
Solar III 10	193385.52	12.61
Solar III 20	297476.06	9.70
Solar III 40	324325.26	5.29
Solar III 60	227026.41	2.47

Net Savings refers to the difference in University electricity cost with and without this specific solar farm

[3] Abbott electricity generation costs about $27/MWh according to the AEI study. This is also about the average (supply) price of grid electricity. However, grid electricity is often priced below average in the winter, in which case it may be more cost-effective to reduce Abbott generation.

[4] In the AEI study, Solar Farm 2 was modeled as a fixed-tilt array, like Solar Farm 1.

The table below shows the annual solar energy production and the amount that is exported to the grid. Solar Farm 3 (20 MW) produces 30,672 MWh/yr, more than the expected production of Solar Farms 1 and 2 combined (25,000 MWh/yr). Of this amount, 8720 MWh is exported to the grid. If the load of Blue Waters is removed, the amount exported to the grid rises to 16,413 MWh.

With Blue Waters With Wind		
	Annual Specific Output (MWh)	**Annual Specific Export (MWh)**
Wind	23991.60	1729.65
Solar II	18034.72	1358.06
Solar III 10	15336.10	3068.78
Solar III 20	30672.19	8720.92
Solar III 40	61344.38	26816.61
Solar III 60	92016.58	50467.69

Without Blue Waters With Wind		
	Annual Specific Output (MWh)	**Annual Specific Export (MWh)**
Wind	23991.60	6580.29
Solar II	18034.72	4439.32
Solar III 10	15336.10	6878.75
Solar III 20	30672.19	16413.74
Solar III 40	61344.38	40316.00
Solar III 60	92016.58	67547.07

With Blue Waters Without Wind		
	Annual Specific Output (MWh)	**Annual Specific Export (MWh)**
Solar II	18034.72	823.04
Solar III 10	15336.10	2360.97
Solar III 20	30672.19	7266.46
Solar III 40	61344.38	24042.68
Solar III 60	92016.58	46824.66

Without Blue Waters Without Wind		
	Annual Specific Output (MWh)	**Annual Specific Export (MWh)**
Solar II	18034.72	3423.41
Solar III 10	15336.10	5991.78
Solar III 20	30672.19	14689.46
Solar III 40	61344.38	37579.74
Solar III 60	92016.58	64232.07

Specific Output refers to output of that Solar Farm alone

Conclusion

Our study shows that a third solar farm of capacity 20+ MW yields considerable cost savings, more than doubles on-campus solar electricity generation, and results in at least half of the solar electricity being used on campus rather than being exported. A solar farm of this size requires about 100 acres, and could fit comfortably on the land lying between Solar Farms 1 and 2.