White Paper

Placing Your Bets on Solar and Scarcity in ERCOT

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Shareables

- The potential for large solar additions in ERCOT threatens to suppress scarcity further in the near term, but in the long term its total impact will be limited as net load shifts.
- Thermal assets do face modest risks of delayed market recovery in the near term from increased solar, but will realize increased scarcity opportunities in the evening.
- Solar projects should be cautious not to count too heavily on high scarcity payments, and continue to find opportunities based on the improving economics of solar.

Executive Summary

As 2017 shapes up to be another year with very low scarcity, Texas generation owners wait anxiously for supply/demand conditions to tighten. With slowing interest in new gas builds and strong demand growth, many are predicting increased scarcity pricing in the next 2-3 years. However, the potential for large scale solar additions in West Texas has been flagged as a concern for thermal generators waiting for higher scarcity. As of the July 2017 interconnection queue, over 21 GW of solar projects are registered, more than double the level from July 2016. For these solar projects themselves, developers may count on monetizing a significant portion of higher future scarcity pricing in order to make the project economics work.

ERCOT ORDC

The ORDC is ERCOT's substitute for a capacity market that works in real-time instead of forward contracting. Using historical data, it calculates the probability of losing load within the next 30-60 minutes, based on the total available capacity and current demand. It then picks a value of lost load (currently $9,000/MWh), and by multiplying the probability of losing load with the value of lost load, it creates a real-time price for capacity reserves.

The Questions Around Solar in ERCOT

The key question is how much solar will affect potential scarcity hours. Scarcity is produced by the operating reserve demand curve (ORDC), which raises prices in real time as reserves drop. This sets up a conflict: solar needs to be producing during scarcity hours to realize high prices, but significant solar production in those hours reduces the scarcity prices for everyone (because of their contribution to reducing net load).

ERCOT's estimate of solar's contribution towards reserve margin (77%) is probably overstated. That figure is based on the average output over the top 20 load hours. However, in the past several years, the top load hours have not entirely correlated with scarcity price events. Scarcity, as produced by the ORDC, is a better indicator of the need for system capacity. Since inception in late 2014, on average, a solar plant in West Texas has realized[1] approximately 44-53% of the scarcity in the market.

EXHIBIT 1: WEST HUB SCARCITY AND REALIZED SOLAR SCARCITY 2015-2017 (AUGUST)

Year	RT Scarcity at West Hub ($/kW)	Solar Scarcity Realization
2015	$19.7	52%
2016	$16.8	53%
2017 thru 8/8	$9.8	44%

Source: ICF

The past three years have all been under conditions of relative oversupply; relatively little scarcity has been produced during the summer peak hours. As supply/demand tightens, it can be expected that increased scarcity will occur during peak demand hours, when the system struggles to meet peak load. This may boost the realization up somewhat: in our modeling, we see approximately 60% scarcity realization as the ceiling.

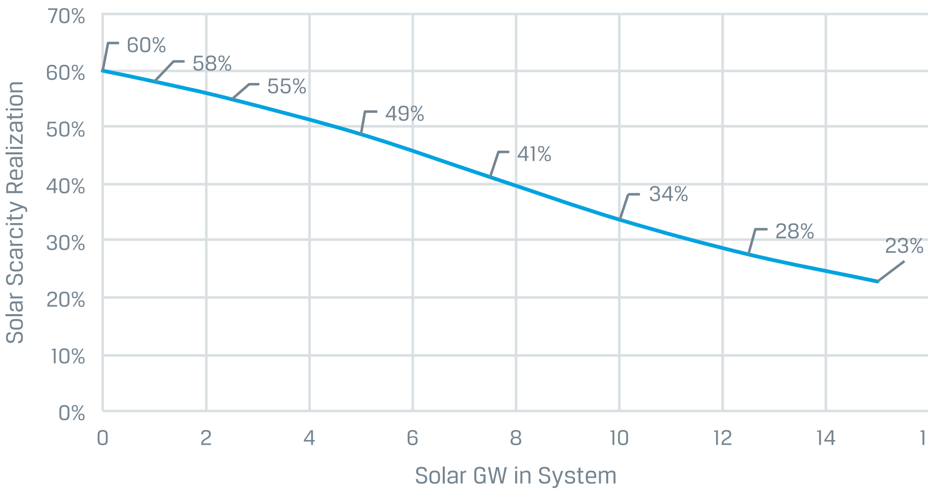
The Shift In Peak Paradox

At the same time, as more solar enters the system, the net peak (subtracting non-dispatchable resources) will shift later into the evening, as has happened in California and other systems. The ORDC measures dispatchable operating reserves, so scarcity will similarly shift later, and solar will realize progressively less scarcity.

[1] Realization, in the case, refers to production during scarcity hours. For example, if solar plants output at full nameplate capacity during all scarcity hours, realization would be 100%. High realization means high revenues and high effectiveness in responding to market needs for capacity.

Our modeling indicates the following contributions of solar to system scarcity, in a system which is otherwise approximately in supply/demand equilibrium (at 77 GW gross peak):

EXHIBIT 2: SOLAR SCARCITY REALIZATION WITH INCREASED SOLAR PENETRATION



Source: ICF

The gross peak load hour has historically often been the hour beginning 4pm. As solar quantities increase, the net peak load, and maximum scarcity, shift forward. Wind capacity has a countering impact, since production ramps up from its mid-day low to higher levels as the evening progresses. However, the decrease in solar production is more pronounced: between 4pm and 7pm in August, wind ramps up by approximately 4-5% (of nameplate capacity), but solar drops from about 73% to near zero. Therefore, the net peak load hour shifts accordingly:

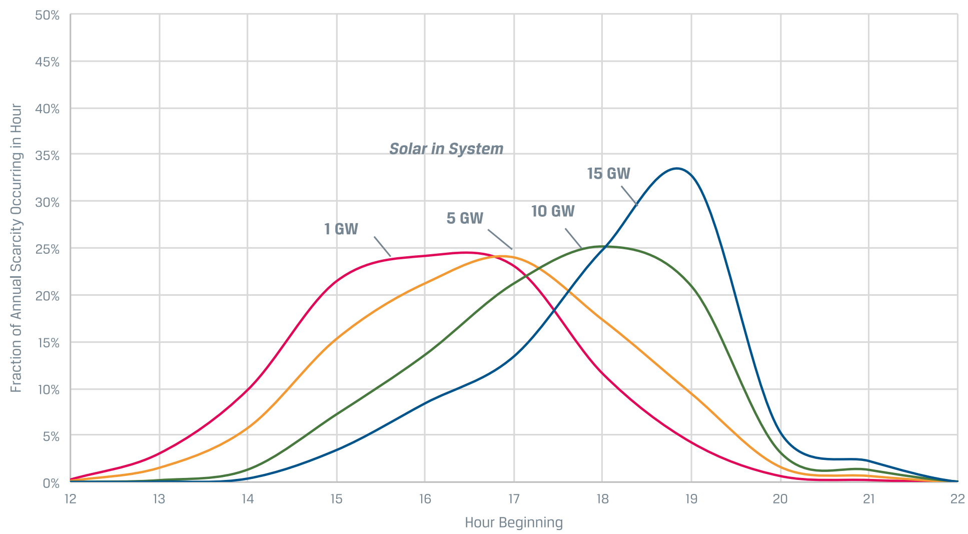
EXHIBIT 3: SHIFT IN PEAK LOAD HOUR WITH SOLAR PENETRATION

Solar GW in System	0	2.5	5	7.5	10
Net Peak Load Hour	4-5pm	4-5pm	5-6pm	6-7pm	7-8pm

Source: ICF

This shift can also be seen in the distribution of scarcity by hour:

EXHIBIT 4: DISTRIBUTION OF SCARCITY BY HOUR



Source: ICF

For solar plants, this means that scarcity revenues are vulnerable to a sort of tragedy of the commons – if many plants decide to come online on the basis of high scarcity forecasts, they will cannibalize each other's chances at that scarcity. One important condition of this is the significant correlation between solar output across the major development areas in the state. As shown below, correlation coefficients between hourly insolation at across the West and Panhandle areas are high: because of concentrated development, solar in ERCOT will tend to produce as a group.

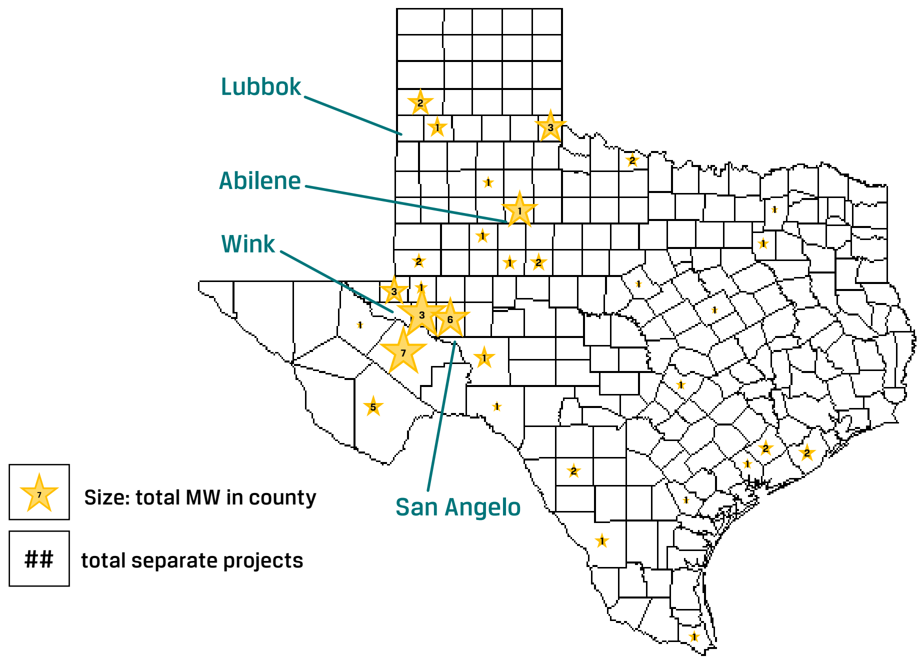
EXHIBIT 5: HOURLY INSOLATION COEFFICIENTS FOR ERCOT WEATHER STATIONS

Weather stations hourly insolation correlation coefficients	Wink	Abilene	Lubbock	San Angelo
Wink	-	0.87	0.89	0.88
Abilene		-	0.90	0.92
Lubbock			-	0.89
San Angelo				-

Source: ICF, NOAA

Projects in the interconnection queue by total projects per county (number) and total MW (size of star), with the four weather stations shown above plotted:

EXHIBIT 6: PROJECT INTERCONNECTION QUEUE ERCOT



Thermal Access to Peak and Scarcity

For thermal generators, this means that total scarcity mitigation due to solar has its limits. In our modeling with a system peak of around 75-80 GW, when measured by scarcity realization, total solar contribution begins to flatten out at around 3.5-4 GW of equivalent impact with 10-15 GW of solar. This is not to say that more solar is not useful to the system, but it suggests that past that point, the net load is nearly completely shifted into the nighttime (4 GW being approximately the average difference in load between the gross peak at 4pm hour and load during 7pm hour). Past this point, capacity will be needed from other sources (incentivized by the concomitant scarcity pricing during these later hours).

This is also not to entirely minimize the impact—four gigawatts of peak impact is akin to 2-3 years of demand growth, delaying higher scarcity – but it does suggest a light at the end of the tunnel, if solar does come online in large quantities.

For thermal, there is another upside: the "long tail" effect (extreme outcomes) for solar are towards less than expected production, while for wind, the experience has been greater than expected production. To put it in numbers: the median output of solar at 4-5pm in August, as a block, is around 80-85% of nameplate capacity. That doesn't leave a lot of room to unexpectedly show up much,

much higher than expected (and wipe out scarcity), but it does leave room for downside: the 10th percentile low outcome is only about 25-30% (contributing to scarcity conditions). In contrast, wind during the same time has a median output of around 16%. As we have written before, with wind, there is potential for low output contributing to scarcity, but with solar the degree of potential scarcity upside could be even higher.

EXHIBIT 7: RENEWABLE GENERATION OUTPUT CONTRIBUTING TO SCARCITY 4-5PM HOUR

Output, fraction of nameplate at 4-5pm hour	Solar	Wind
90th Percentile High Output	92%	33%
Median Output	82%	16%
10th Percentile Low Output	27%	5%

Source: ICF

It is possible for both solar and thermal to succeed in the market. Large amounts of solar will simply push scarcity to the nighttime hours, where the ORDC will compensate dispatchable generation. New solar projects should not rely too heavily on projections of scarcity. However, as a hedge against higher gas prices and power price volatility, solar is still an attractive option for power buyers.

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