Growing Evidence of Increased Frequency of Negative Electricity Prices in U.S. Wholesale Electricity Markets

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See footnotes at end of text.

SUMMARY

The significant increase in the supply of renewable resources in California and Texas is contributing to notable growth in the incidence of negatively-priced hourly energy in these states' wholesale electricity markets.[1] Although the incidence of negative prices is less pronounced in other geographic regions of U.S., it has also grown in specific geographic regions of the PJM Interconnection and the New York Independent System Operator (NYISO). As renewable portfolio standard requirements continue to increase, negative pricing frequency can be expected to occur more often, and similarly impact New England and the Midwest and southwestern regions of the U.S.

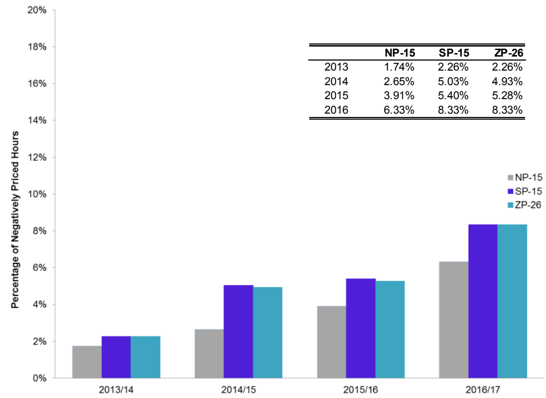
The increased incidence of negative pricing can be linked to two characteristics associated with U.S. renewable energy resource development. First, renewable resources receive production-based subsidy payments from the U.S. federal government, and from most states where renewable portfolio standards are used to encourage these resources' development.[2] Because these subsidies are paid only when the renewable resource produces energy, resource owners that are required to make offers into wholesale electric energy markets are willing to pay the system operator to accept their production (i.e., make negatively-priced offers). These resource owners are willing to pay the system operator up to the total of their subsidy payments given that they will realize revenue based on the difference of their subsidy payment and what they pay the system operator to take their production.

Second, most renewable resource production is maximized when the wind blows and the sun shines. The periods when renewable resource production is maximized are at night and mid-day, which do not correspond to when consumer demand from electricity is highest. Thus, as renewable resource supply has increased, it can outpace demand, leading to a potential oversupply of electric generation. During these periods of oversupply, generation resources that prefer to, or must, continue to supply electricity even as prices decline will make negatively-priced offers to the system operator in order to continue producing. When excess supply is large enough, sellers will compete to remain operational using negatively-priced offers. Although accommodating negatively-priced offers is important for system operators to efficiently back down generation resources, subsidized resource production driven by production subsidy payments will contribute to more aggressive negatively-priced offers than would otherwise occur.

Negative prices resulting from the subsidization of zero pollutant emission resources artificially lowers electric energy prices. If the unpriced externalities associated with the production of electricity from fossil fuel resources were internalized in electric energy prices, the energy prices would increase, signaling the estimated cost to society of the associated pollutants. Increasing prices through appropriate internalization of the external costs not captured in the marketplace would benefit producers by increasing the value of resources that are low, or zero, emission and signal to consumers the increased societal costs of consuming electric energy. By artificially lowering energy prices, renewable resource subsidization policies are distorting market prices away from more efficient outcomes.

Moreover, over the long-term, the dynamic efficiency of the power market will be affected as forward market prices incorporate expectations of artificially lower spot market prices. This can be expected to affect the resource mixture as energy market prices that otherwise internalize the unpriced external cost of pollutants would result in higher-emitting resources being supplanted by lower-emitting resources, and these higher-emitting resources become those most likely to retire and be replaced by new, higher-efficiency, lower-emitting resources. In contrast, renewable production subsidies create financial challenges for the least competitive resources, not necessarily the highest emitting resources.

Absent a change in renewable subsidization policies, or actions taken by Independent System Operators (ISOs) to diminish the frequency of negative prices, the incidence of negative prices is poised to continue to grow. Renewable resources are already zero marginal cost resources and the impact of subsidization policies that incentivize negatively-priced offers should be minimized or eliminated.



	NP-15	SP-15	ZP-26
2013	1.74%	2.26%	2.26%
2014	2.65%	5.03%	4.93%
2015	3.91%	5.40%	5.28%
2016	6.33%	8.33%	8.33%

Figure 1A. Percentage of Negatively-Priced Hours at CAISO Hubs, Hourly Real-time Average Prices, 2013 - 2016
Source: Ventyx.

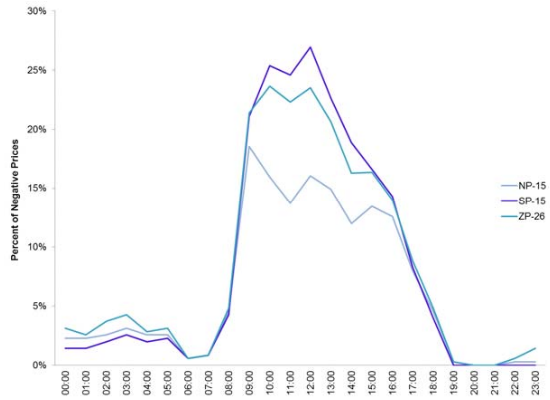
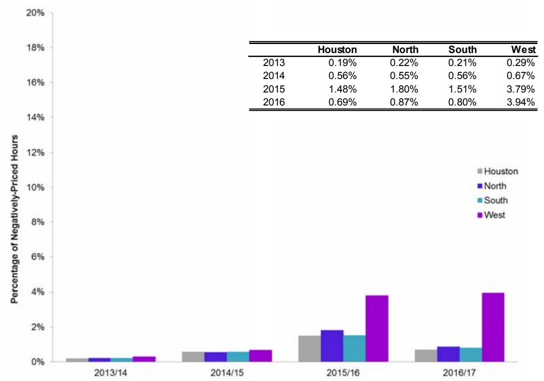


Figure 1B. Frequency of Negative Prices at CAISO Hubs in Each Hour, Hourly Real-time Average Prices, 2016
Source: Ventyx.



	Houston	North	South	West
2013	0.19%	0.22%	0.21%	0.29%
2014	0.56%	0.55%	0.56%	0.67%
2015	1.48%	1.80%	1.51%	3.79%
2016	0.69%	0.87%	0.80%	3.94%

Figure 2A. Percentage of Negatively-Priced Hours at ERCOT Hubs, Hourly Real-time Average Prices, 2013 - 2016
Source: ERCOT

SELECTED U.S. ISO NEGATIVE ELECTRIC ENERGY MARKET PRICING FREQUENCY AND DIURNAL INCIDENCE

The following sections present analyses of the frequency and incidence of negative pricing in select U.S. ISOs. These results are derived by analyzing the reported hourly average real-time locational marginal prices at various ISO hubs (or the average of four fifteen-minute settlement point prices at Electric Reliability Council of Texas (ERCOT) hubs). The frequency of negatively-priced hours is reported as a percentage of total hours in each year (defined as June 1 – May 31) from June 1, 2013 to May 17, 2017. The diurnal incidence of negative prices during the hours of the day are presented by calculating the percentage of reported prices that were negative in each hourly interval (0:00 to 23:00) for 2016/17. These hourly percentages show the pattern of when negative prices are most prominent.

California Independent System Operator (CAISO)

The proportion of negatively-priced hours in California has grown in each year and in each of CAISO's zones over the period 2013/14-2016/17 (Figure 1A). In 2013/14, between 1.7% and 2.3% of all hours were priced negative. By 2016/17, between 6.3% and 8.3% of hours were priced negative, with the incidence of negative pricing higher in the Southern California zones when compared to California's Northern zone. The higher frequency of negative prices in Southern California is likely driven by the much greater proportion of renewable resources located in the Southern part of the state.

Examining the data from a diurnal perspective reveals that the percentage of negative prices is concentrated into those hours of the days in which renewable resource production is greatest. Figure 1B shows that negative prices in 2016/17 occurred more frequently in the middle of the day when solar powered resources are most productive (between 8:00 a.m. and 6:00 p.m.), and that the percentage of negative prices in some of these daytime hours is greater than 20%. For example, in CAISO's SP-15 zone, approximately 27% of hours ending 12:00 p.m. were priced negative in 2016. The effects of the substantial growth in solar powered resources in California is clearly resulting in negative pricing exasperating financial difficulties of natural gas generation resources that serve as back-up supply when unexpected variations in renewable resources occur. Note also that the majority of negative prices (more than 97%) in CAISO's three pricing zones were in the -$50 to $0/MWh range, likely driven by production subsidies.

ERCOT

Negative pricing has also been growing at ERCOT's pricing hubs from 2013/14-2016/17 (Figure 2A). At the Houston, North, and South hubs, the highest proportion of negative pricing occurred in 2015 with between 1.5% and 1.8% of hours priced negative. The incidence of negative pricing at the West hub has grown in each year over 2013/14-2016/17, and over the last two years has been more than double the proportion at the other three hubs (3.9% of hours were priced negative at the West hub in 2016/17). This corresponds to the substantial growth in wind resources in Texas over the last several years.

Figure 2B also shows that the negative prices tend to concentrate in the early morning (between midnight and 7:00 a.m.) hours at ERCOT hubs consistent with greater production from wind resources during the overnight time period. The most frequently negatively-priced hour in 2016/17 was the hour ending 3:00 a.m. at all hubs, priced negative close to 4% of the time at the Houston, North, and South hubs and over 11% of the time at the West hub. All but one instance of negative pricing fell in the -$50 to $0/MWh range at ERCOT's pricing hubs.

NYISO

Figure 3A shows that in the NYISO negative pricing frequency has grown in the upstate Western, Genesee, Central, Northern, and Mohawk Valley zones, with the highest proportion of negative prices observed in 2015/16. The percentage of negatively-priced hours in the Western, Genesee, Central, and Mohawk Valley zones grew from approximately 0.4% in 2013/14 to between 2.2% and 3.5% in 2015 (down to between 1.2% and 1.8% in 2016). NYISO's Northern zone has a significantly higher proportion of negative prices than the rest, similar to that seen in the CAISO. Over 8.5% of hours were priced negative in the Northern zone in 2015/16 and over 6.5% in 2016/17.

Figure 3B shows that negative prices occurred more often in the hours between midnight and 7:00 a.m. during 2016/17 consistent with the production profile of wind resources. However, negative prices occur throughout the day. The most frequently negative hour in the Western, Genesee, Central, and Mohawk Valley zones was the hour ending 6:00 a.m., priced negative approximately 5% of the time. In the Northern Zone, the most frequently negative hour was the hour ending 2:00 a.m., priced negative nearly 11% of the time. Almost 94% of negative prices across all NYISO hubs fell in the -$50 to $0/MWh range.

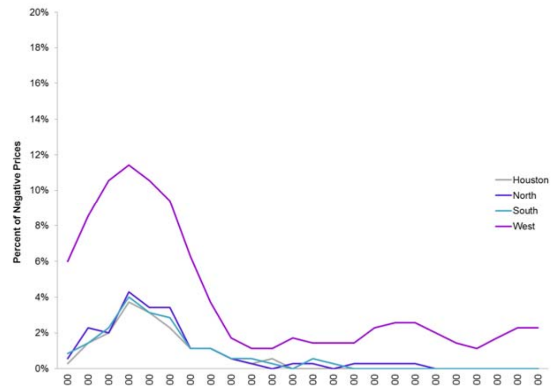


Figure 2B. Frequency of Negative Prices at ERCOT Hubs in Each Hour, Hourly Real-time Average Prices, 2016
Source: ERCOT.

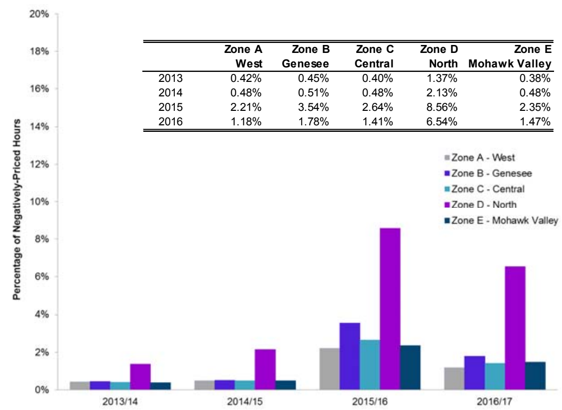


Figure 3A. Percentage of Negatively-Priced Hours at NYISO Hubs, Hourly Real-time Average Prices, 2013 - 2016
Source: Ventyx.

PJM

Negative prices have only been prevalent at PJM hubs and pricing nodes located in Illinois over the last four years (see Figure 4A). While the pricing hubs have had limited incidence of negatively priced hours in any year between 2013/14 and 2016/17, nuclear generation hubs located in Western Illinois have faced negative prices as much as 10-11% of the hours during the year in 2015/16. In addition, during this time period PJM's independent market monitor has reported rising, falling, and most recently increased frequency of wind power resources being a marginal source of generation supply in PJM's markets.

Although negative prices do not appear to be an issue across PJM's region in total, they are far more prevalent in certain areas in the western part of PJM where wind resources are concentrated and where the nuclear generation facilities Quad Cities and Byron are located in Illinois. Figure 4B shows that the proportion of hours that are priced negative is significantly higher at the Quad Cities and Byron nodes than any of PJM's hubs over the period 2013/14-2016/17. The incidence of negative pricing was particularly high in 2015/16, with nearly 11% of hours priced negative at the Byron node and just over 10% at the Quad Cities node. These areas in particular saw negative prices occur in each hourly interval of 2016/17. The hour ending 6:00 a.m. was priced negative between 6.8-8.5% of the time in Byron, and the hour ending 7:00 a.m. was priced negative over 9% of the time in Quad Cities. 80% of negative prices at these nodes were in the -$50 - $0/MWh range, with a further 16% in the -$150 to -$50/MWh range.

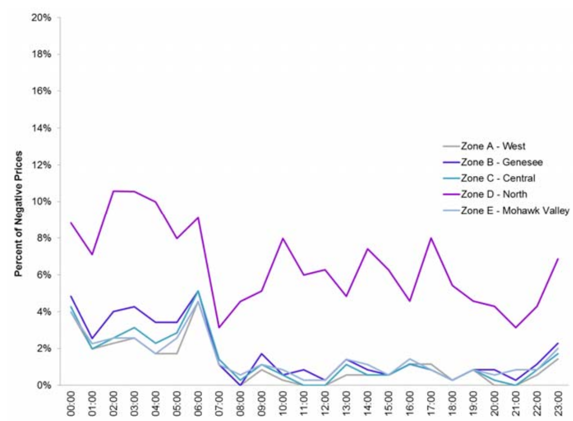
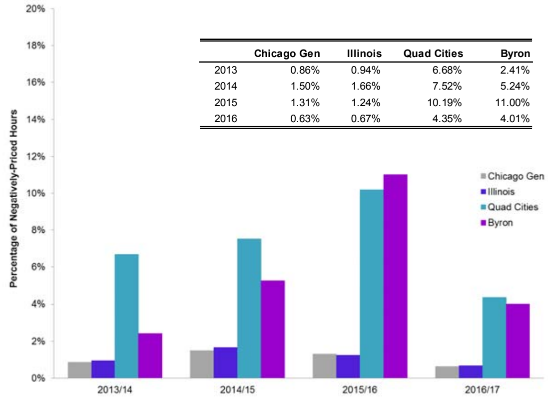


Figure 3B. Frequency of Negative Prices at NYISO Hubs in Each Hour, Hourly Real-time Average Prices, 2016
Source: Ventyx

ISO-NE

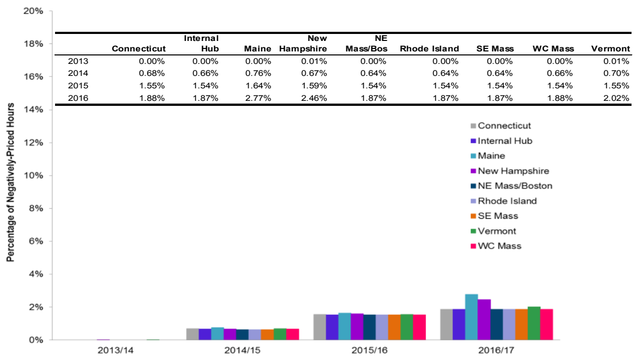
In 2013, there were practically no incidences of negatively-priced hours in ISO-NE. That has changed in the following years, growing to between 1.8% and 2.8% across ISO-NE's hubs in 2016 (Figure 5A). Maine saw the highest percentage of hours priced negative with 2.8%, followed by New Hampshire and Vermont with 2.5% and 2% respectively. As with ERCOT, NYISO, and PJM, negative prices tended to



	Chicago Gen	Illinois	Quad Cities	Byron
2013	0.86%	0.94%	6.68%	2.41%
2014	1.50%	1.66%	7.52%	5.24%
2015	1.31%	1.24%	10.19%	11.00%
2016	0.63%	0.67%	4.35%	4.01%

Figure 4A. Percentage of Negatively-Priced Hours at PJM Hubs, Hourly Real-time Average Prices, 2013 - 2016
Source: Ventyx

Figure 4B. Frequency of Negative Prices at PJM Hubs in Each Hour, Hourly Real-time Average Prices, 2016
Source: Ventyx



	Connecticut	Internal Hub	Maine	New Hampshire	NE Mass/Bos	Rhode Island	SE Mass	WC Mass	Vermont
2013	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.01%
2014	0.68%	0.66%	0.76%	0.67%	0.64%	0.64%	0.64%	0.66%	0.70%
2015	1.55%	1.54%	1.64%	1.59%	1.54%	1.54%	1.54%	1.54%	1.55%
2016	1.88%	1.87%	2.77%	2.46%	1.87%	1.87%	1.87%	1.88%	2.02%

Figure 5A. Percentage of Negatively-Priced Hours at ISO-NE Hubs, Hourly Real-time Average Prices, 2013 - 2016
Source: Ventyx

occur more frequently in the early morning hours between midnight and 7:00 a.m. when wind resource production is most prevalent, with some hours priced negative around 7% of the time in 2016 (Figure 5B). Maine in particular saw negative prices occur in each hourly interval. 82% of negative price occurrences at ISO-NE hubs were in the -$50 to -$0/MWh range, with a further 16% in the -$150 to -$50/MWh range.

The data presented in Figures 1-5 clearly show that the frequency and incidence of negatively-priced electric energy corresponds to the production profiles of renewable resources. The penetration of renewable resources increased substantially in recent years in both California and Texas, and the impact on electric energy market pricing coincides with the growth in supply of these resources. Absent specific contractual terms or ISO rules that minimize or reduce the impact of negative priced offers, U.S. States that are planning to significantly increase reliance on renewable resources through production-based subsidization programs will increase incidence of negatively-priced electric energy as we have seen in California in Texas.

Footnotes

[1] See, for example, California ISO Department of Market Monitoring, 2016 Annual Report on Market Issues and Performance, May 2017 at 98-101 and Potomac Economics, Independent Market Monitor for ERCOT, 2016 State of the Market Report for the ERCOT Electricity Markets, May 2017 at 11.

[2] See U.S. Department of Energy, "Renewable Electricity Production Tax Credit (PTC)," at https://energy.gov/savings/renewable-electricity-production-tax-credit-ptc and NC Clean Energy Technology Center, Database of State Incentives for Renewables & Efficiency, at http://www.dsireusa.org/

[3] Generation resource data reported by the CAISO show that 75-80% of solar and wind power resources are located in Southern California. See Master Control Area Generating Capability List at https://www.caiso.com/participate/Pages/Generation/Default.aspx, accessed August 3, 2017.

[4] La Paloma, a 1,200 MW combined cycle plant, cited a rise in renewable generation in California as one of its main reasons for filing for bankruptcy. See "California gas power plant La Paloma files for bankruptcy," Reuters, December 6, 2016 at http://www.reuters.com/article/us-la-paloma-bankruptcy-idUSKBN13V2PY. Calpine has also been facing financial trouble to the point of considering a sale of its assets – the company took one of its natural gas plants, the Sutter Energy Center, offline due to poor economics resulting from increased renewable penetration and saw another one of its combined cycle plants operating at 14% capacity. See Nichola Groom, "Unlikely casualty in California's renewable energy boom: natural gas," Reuters, June 9, 2016 at http://www.reuters.com/article/us-california-energy-analysis-idUSKCN0YV0BX and John Dizard, "The private equity arms race is hotting up," Financial Times, July 8, 2017 at https://www.ft.com/content/2e61b5ec-625a-11e7-91a7-502f7ee26895.

[5] Between the end of 2010 and Q2 2017, installed wind capacity in Texas more than doubled from 10,085 MW to 21,044 MW. See American Wind Energy Association, AWEA U.S. Wind Industry Annual Market Report, 2010, at 11 and American Wind Energy Association, U.S. Wind Industry Second Quarter 2017 Market Report, 2017, at 6.

[6] Note that nuclear units are typically scheduled and paid based on day-ahead market prices and do not realize negative real-time prices. However, suppressed real-time prices will put downward pressure on forward market prices as the market place adjusts to a greater incidence of negative prices.

[7] Monitoring Analytics, Q2 2017 State of the Market Report for PJM at 104.

[8] See U.S. Department of Energy, Staff Report on Electricity Markets and Reliability, August 2017, at 77, which shows a large concentration of wind resources in Northern Illinois and Iowa. Byron and Quad Cities are located in northwestern Illinois with Quad Cities located right at the border of Iowa.

[9] For example, Massachusetts and Connecticut each have recently passed legislation that calls for long-term contracts to support a substantial increase in renewable resource development effectively bringing forward compliance with future RPS obligations (Mass. Acts 188, 2016 and Connecticut Public Act No. 13-303, 2013).

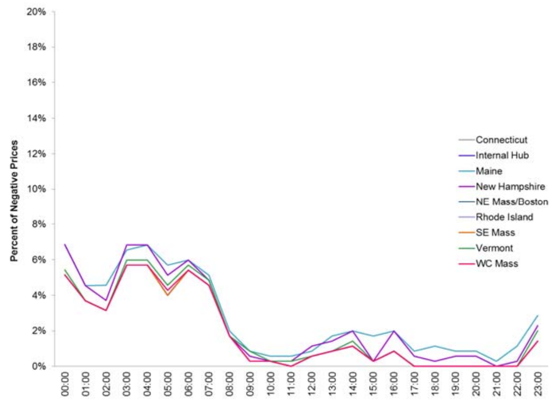


Figure 5B. Frequency of Negative Prices at ISO-NE Hubs in Each Hour, Hourly Real-time Average Prices, 2016

Source: Ventyx

Irie (*references continued from page 35*)

[4] Gas Exporting Countries Forum (GECF) (2017). The GECF History, https://www.gecf.org/_resources/files/pages/history/gecf-history-file.pdf

[5] International Partnership for Energy Efficiency Cooperation (IPEEC) (2017). Introduction, https://ipeec.org/cms/1-introduction-.html

[6] International Atomic Energy Agency (IAEA) (2017). History, https://www.iaea.org/about/overview/history

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MEMBER GET A MEMBER CAMPAIGN A SUCCESS

Jacek Kaminski Wins Complimentary Registration to attend the

Vienna European Conference

IAEE's *Member Get a Member* campaign was another smashing success in the May 1 to July 31 period.

Members had their membership expiration date advanced three months for each new member referred.

With seven referrals, Jacek Kaminski of the Polish Academy of Sciences referred the most new members. He won a complimentary registration to the European Conference in Vienna this September.