DOES ELECTRICITY GET CHEAPER AND CLEANER WITH MORE WIND IN ERCOT?

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Overview

The production of electricity has heavily relied on fossil fuels such as coal and natural gas. With the prospect of transitioning to a low-carbon-intensive power system and owing to various federal or state subsidies such as renewable electricity Production Tax Credit (PTC) and Investment Tax Credit (ITC), zero-emission intermittent renewable resources has rapidly penetrated into the bulk electric grid and changed the generation fuel mix in various ISO/RTOs in the United States.[1] Among all organized wholesale electricity markets in the U.S., the Electric Reliability Council of Texas (ERCOT) has witnessed the most aggressive addition in wind power: installed capacity reached 18.9 GW in 2016, which fulfilled 15.1% of ERCOT load year-round and set a new record of 47% instantaneous wind penetration in the year.[2]

As the share of renewables in the system continue to increase, ERCOT faces new operational challenges such as renewable energy forecast errors, net load ramps, low inertia, and need for variable ancillary services.[3] Furthermore, subsidized, low-operating-cost wind that gets dispatched when available displaces thermal generation and could reduce nodal prices. As such, increasing penetration of wind is putting downward pressure on financial viability of the thermal generators. Several studies quantified the cost-effectiveness of integrating renewables for emission reduction (Baldick, 2012; National Academy of Sciences, 2013; Deng et al., 2015). Several market participants have also raised concerns on the impact of renewables on the functioning of wholesale markets and grid reliability in the long-term. Aiming to make several contributions to the existing literature as well as ongoing policy discussion, this study uses the particular example of the ERCOT market and tries to revisit the following empirical questions: (1) How does wind integration change the energy price? (2) Has wind displaced emission from thermal generation?

Methods and Data

We utilized Real-Time (RT) 15-minutes Security Constrained Economic Dispatch (SCED) data from 2014 to 2016, including settlement point prices, dispatched MW, and fuel type at resource nodes. We also utilized hourly emissions data from U.S. EPA Continous Emissions Monitoring Systems database at the facility level, including CO_2, NO_X, and SO_2 emissions from coal, natural gas, or petroleum-fired generation facilities.

To estimate the impact of wind generation on nodal prices at non-wind resources, we use the general model:

$$Price_{i,t} = \beta_1 \cdot L_t + \beta_2 \cdot W_t + \beta_3 \cdot NG_t + u_i + \emptyset \cdot Z_t + \varepsilon_{i,t} \qquad (1)$$

where i indexes each non-wind Resource Node and t indexes each 15-minutes observations during 2014 to 2016; and

L_t = Aggregate 15-minutes ERCOT load (MW)
W_t = Aggregate 15-minutes ERCOT wind generation (MW)
NG_t = Natural gas price ($/mmBtu)
u_i = Resource Node dummy
Z_t = Vector of time dummies.

To estimate the relationship between the real-time price of electricity and emissions, we use the following systems of equations.

$$Price_{i,t} = \alpha_1 \cdot Price_{i,t-1} + \alpha_2 \cdot NG_t + \alpha_3 \cdot Coal_t + u_i + \emptyset \cdot Z_t + \delta_{i,t} \qquad (2.1)$$
$$Net\ Load_t = \alpha_1 \cdot \widehat{Price}_{i,t} + \alpha_2 \cdot \widehat{Price}^2_{i,t} + u_i + \emptyset \cdot Z_t + \theta_{i,t} \qquad (2.2)$$

[1] Federal Energy Regulatory Commission, *2016 Common Metrics for RTO/ISOs and Individual Utilities Staff Report*. Accessed at https://www.ferc.gov/legal/staff-reports/2016/08-09-common-metrics.pdf
[2] ERCOT, *Grid Information – Generation*. Accessed at http://www.ercot.com/gridinfo/generation
[3] To address these evolving risks to grid operation, ERCOT added a new “Reliability Risk Desk” in its control room, which went live in January 2017.

$$Emission_{i,t} = \alpha_1 \cdot \widehat{Price}_{i,t} + \alpha_2 \cdot \widehat{Net\ Load}_t + \alpha_3 \cdot W_t + u_i + \emptyset \cdot Z_t + \varepsilon_{i,t} \qquad (2.3)$$

where i indexes each emission facility and t indexes each hourly observations during 2014 to 2016; and

$Net\ Load_t$ = ERCOT Hourly Net Load (MW)
$Coal_t$ = Coal price ($/mmBtu)

The first-stage of the system predicts real-time price of electricity ($Price_{i,t}$) using lagged real-time price ($Price_{i,t-1}$), natural gas prices (NG_t) and coal prices ($Coal_t$). The second-stage of the system predicts hourly net load, i.e. ERCOT load minus generation from wind, using predicted real-time price ($\widehat{Price}_{i,t}$) from the first-stage and squared real-time prices ($\widehat{Price}^2_{i,t}$). In the third-stage of the system, we predict hourly emissions using predicted real-time price ($\widehat{Price}_{i,t}$), hourly net load ($\widehat{Net\ Load}_t$), and wind generation (W_t).

Results[4]

First, wind generation has not displaced fossil-fueled generation in ERCOT between 2012 and 2016 particularly during on-peak hours in summer months, although the installed wind capacity increased from 11 GW to 18.9 GW during the analysis period. Second, our econometric analyses suggest that for every 1,000 MW wind addition in a 15-minute real-time settlement interval would suppress wholesale energy price by $1.5/MWh to $4.5/MWh, depending on peak/off-peak seasons and hours, while holding systemwide load and natural gas price constant. Our preliminary analysis also show that marginal increase in wind generation (i.e., an additional MW generation) increases average emissions from CO2 by 0.006 short tons, SO2 by 0.022 pounds and NOX by 0.01 pounds during on peak hours at a fossil generation facility. During off-peak hours, marginal increase in wind generation increases emissions from CO2 by 0.004 short tons, SO2 by 0.03 pounds and NOX by 0.009 pounds.

Conclusions

In the interest of moving towards a cleaner, more reliable and resilient energy economy, there is a clear and urgent need to understand the effect of integrating renewable resources into the power system as such penetration is undertaking an unprecendented pace. Using the unique example of ERCOT, which is one of the largest electricity markets in the United States with considerable amount of wind capacity, this paper provides empirical evidence on the impacts of increasing wind on wholesale energy prices. In addition, this paper shows the dynamic relationship between renewable and non-renewable resources in electricity generation and its effects on carbon emissions.

References

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[4] All results are preliminary pending further improvement/robustness check.