WIND ENERGY AND NEGATIVE PRICING

Is Production Tax Credit to Blame?

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Production Tax Credit has Stimulated Wind Capacity Growth

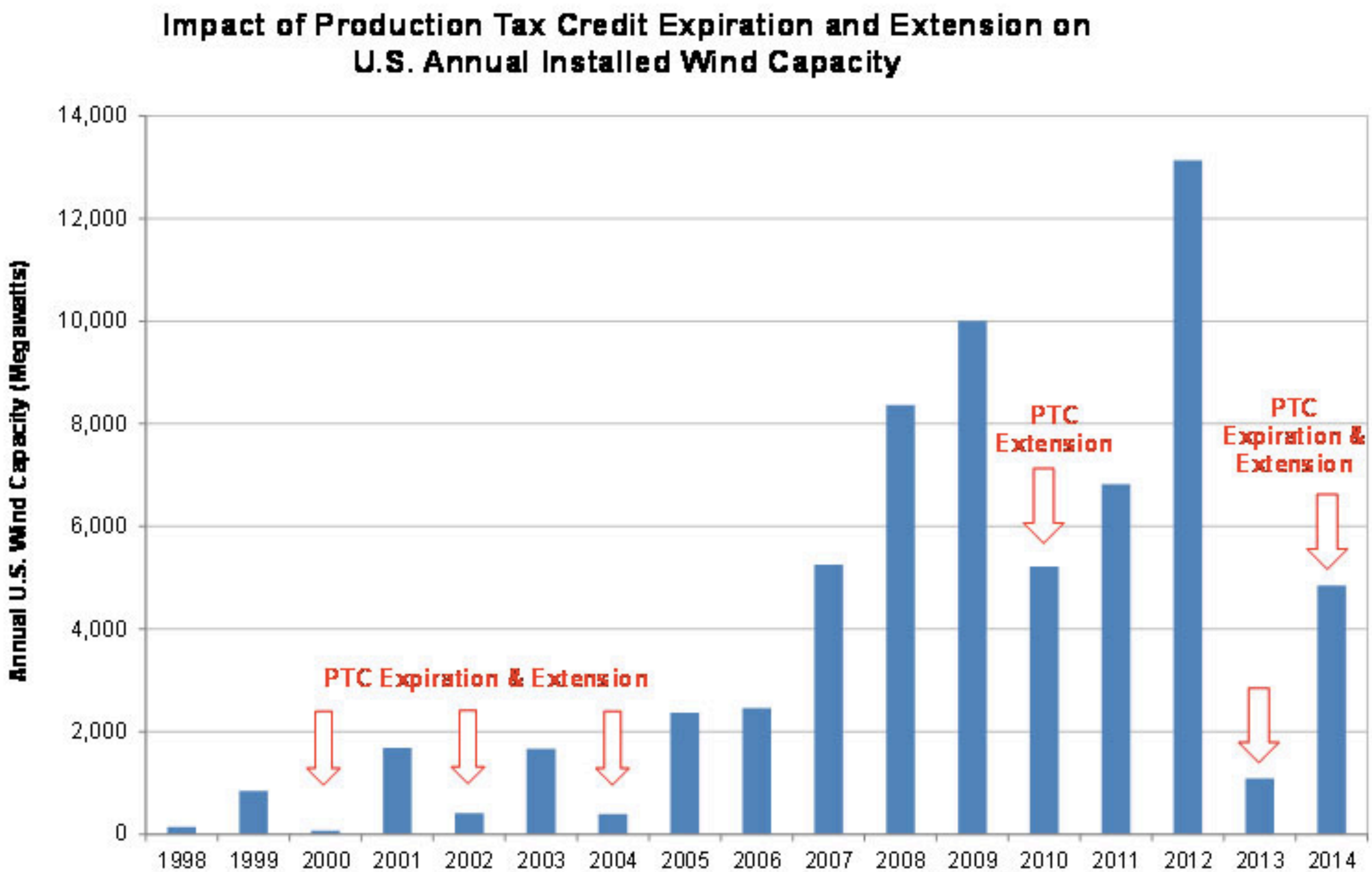
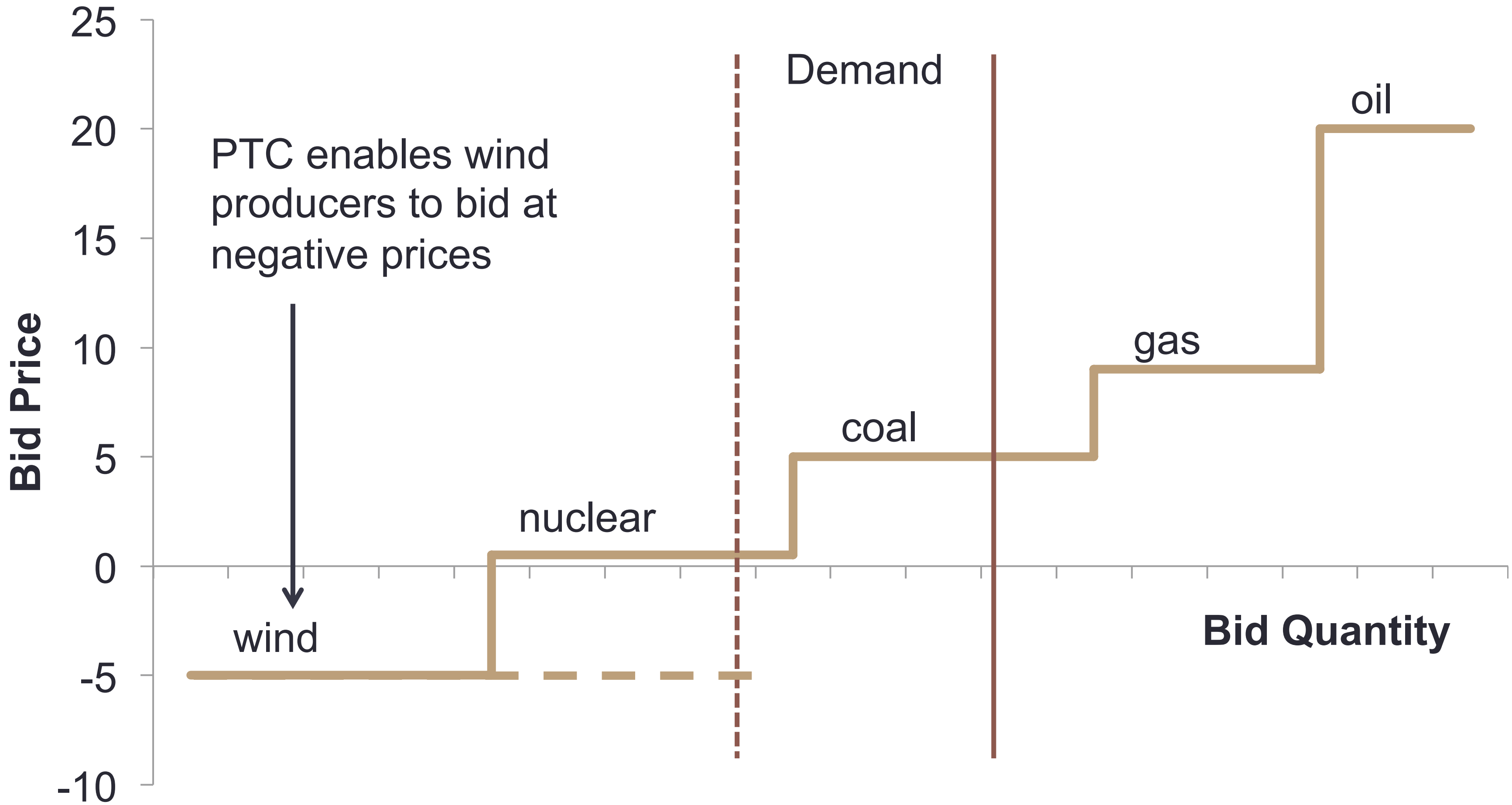


Chart by Union of Concerned Scientists

Negative price is the signal for down-regulation



Wind power and negative prices

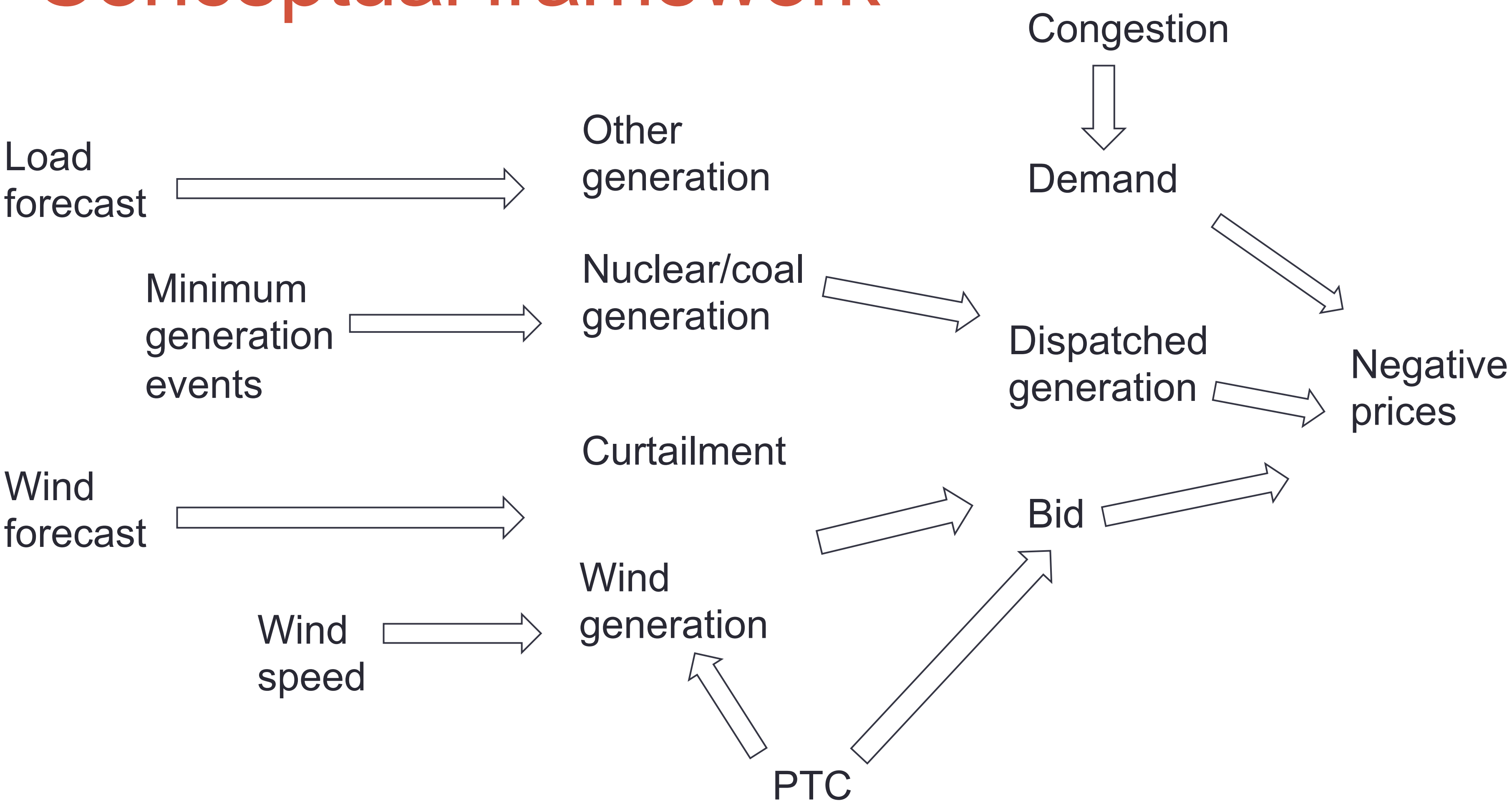
- Wind power production is related to electricity wholesale prices
  - Renewable energy reduce electricity price in wholesale markets (Moreno, López, and García-Álvarez 2012; Traber and Kemfert 2011; Woo et al. 2011)
  - In regions with high wind penetration, wind production can cause spikes of negative prices (Brandstätt, Brunekreeft, and Jahnke 2011; Nicolosi 2010).
- Negative prices are results of system imbalance
  - In the central western European market, negative prices are correlated with forecast errors of load and wind and solar generation (Brijs et al. 2015)
- Negative prices are signals for downward dispatching generation, and reliable grid needs the downward flexibility
- PTC affects wind capacity installation, and enables wind producers to bid in negative prices

Research question

- The “incompressibility of power systems” is a barrier for renewable power integration
- Negative prices are “market distortions” that need to be addressed
- “PTC aggravates the problem of negative pricing”

- Does PTC cause more negative pricing hours?

Conceptual framework



Model

$$D = \alpha + \beta_0 * PTC + \beta_i * X_i + \varepsilon$$

Where, D is the dependent variable, hour of negative prices

β_0 is the coefficient of the policy variable

X_i is the non-policy independent variables, including wind generation, short-term load forecast error, day-ahead mid-term load forecast error, minimum generation events, and transmission outages

β_i is the coefficient of X_i

α is the constant

ε is the error term

Data

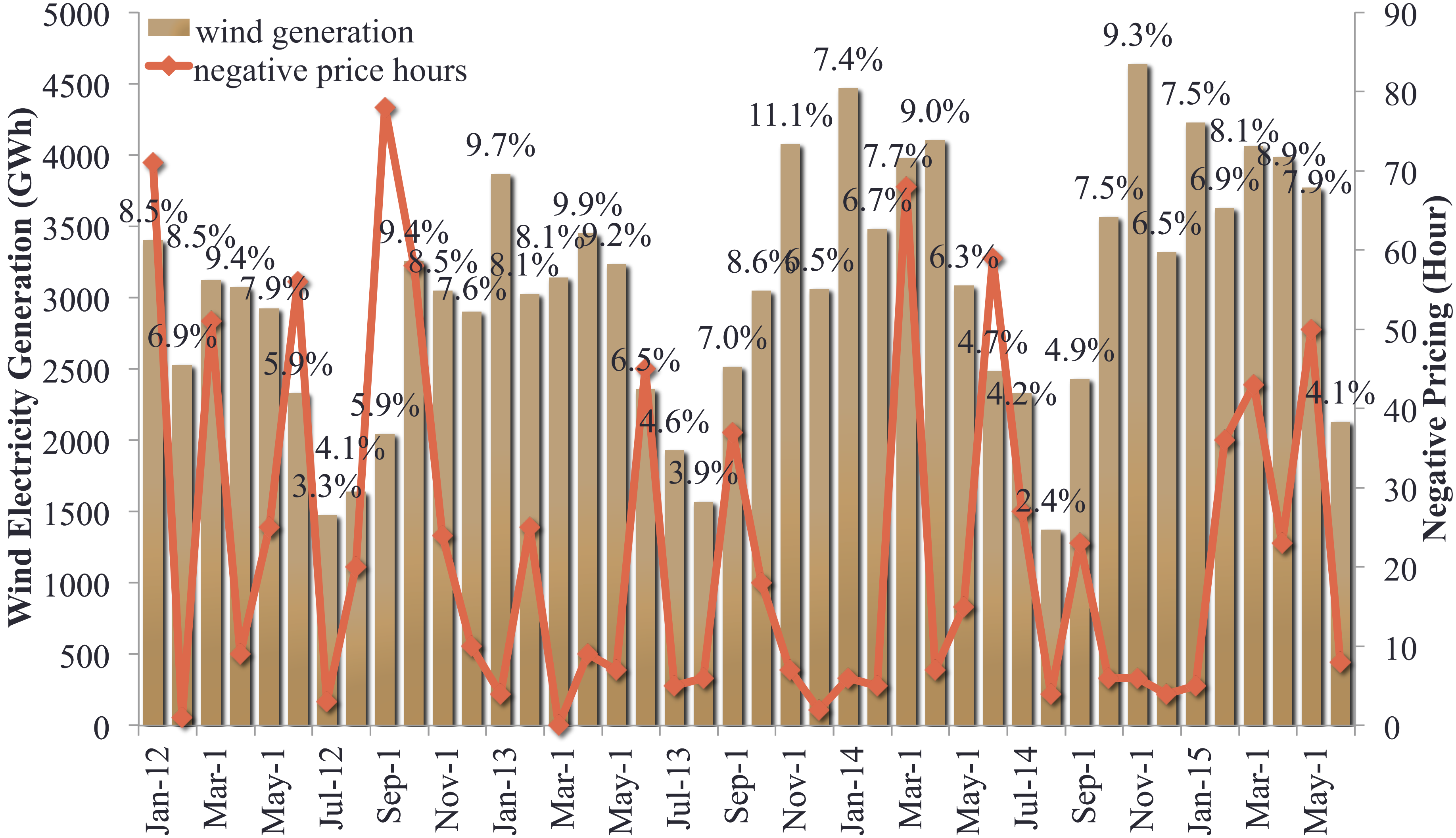
- Real-time LMP
- Four MISO regional trading hubs
  - Michigan hub
  - Indiana hub
  - Minnesota hub
  - Illinois hub
- Data is extracted from MISO’s monthly market assessment reports and information forum presentations
- From 01/2012 to 06/2015

Table 1. Summary of the independent and dependent variables

Variable	Unit	Obs	Mean	Std. Dev.	Min	Max
Negative price	hour	42	23	22.3	0	78
Wind generation	GWh	42	3048.7	836.4	1371	4637
Transmission outage	#	42	3947.2	1160.8	1753	6000
Minimum generation event	#	42	0.2	0.5	0	2
PTC1	-	42	0.4	0.5	0	1
PTC2	-	42	0.6	0.7	0	2
Short-term load forecast error	%	42	0.0084	0.0390	0.0016	0.255
DA mid-term load forecast error	%	42	0.0129	0.0038	0.007	0.0216

Code	PTC1	PTC2
1/12-12/13	1	2
1/14-12/14	0	1
1/15 – 6/15	0	0

Results


wind generation
negative price hours
Wind Electricity Generation (GWh)
Negative Pricing (Hour)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
0
10
20
30
40
50
60
70
80
90
Jan-12
Mar-1
May-1
Jul-12
Sep-1
Nov-1
Jan-13
Mar-1
May-1
Jul-13
Sep-1
Nov-1
Jan-14
Mar-1
May-1
Jul-14
Sep-1
Nov-1
Jan-15
Mar-1
May-1
8.5%
6.9%
8.5%
9.4%
7.9%
5.9%
3.3%
4.1%
5.9%
9.4%
8.5%
7.6%
9.7%
8.1%
8.1%
9.9%
9.2%
6.5%
4.6%
3.9%
7.0%
8.6%
11.1%
6.5%
7.4%
6.7%
7.7%
9.0%
6.3%
4.7%
4.2%
2.4%
4.9%
7.5%
9.3%
6.5%
7.5%
6.9%
8.1%
8.9%
7.9%
4.1%

Results

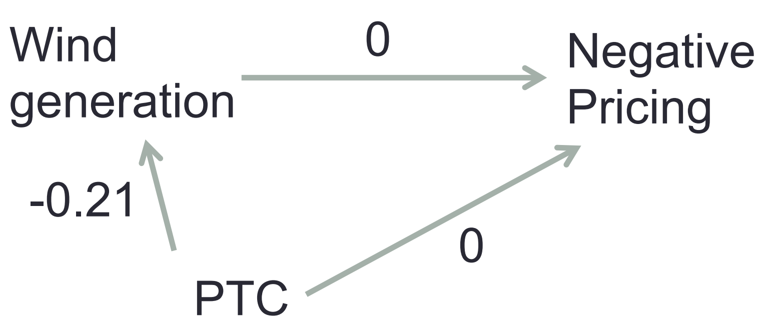
Table 3. Regression results for negative pricing hours

Variable	Model 1		Model 2	
	Coefficient	Robust Std. Err.	Coefficient	Robust Std. Err.
PTC1	-7.8	7.7	-	-
PTC2			-6.5	4.5
lg(Wind generation)	-10.4	14.5	-12.7	13.9
lg(Short-term load forecast error)	74.7*	33.4	80.1**	29.1
lg(Day-ahead mid-term load forecast error)	11.1	16.9	12.5	16.7
Minimum generation event	26.2**	4.8	25.4**	5.0
lg(Transmission outage)	4.6	11.6	4.2	12.0
constant	568	304	633	271
R^2	0.3844		0.3906	

* $p<0.05$, ** $p<0.01$

Testing indirect effect

Dependent Variable	lg(Wind generation)		lg(Wind generation)		Negative Prices		Negative Prices	
	Coeff.	Robust Std. Err.	Coeff.	Robust Std. Err.	Coeff.	Robust Std. Err.	Coeff.	Robust Std. Err.
PTC1	-0.21**	0.07	-	-	-5.7	7.5	-	-
PTC2	-	-	-0.20*	0.10	-	-	-6.3	8.2
lg(Short-term load forecast error)	1.34**	0.31	1.18**	0.31	60.7*	27.7	57.0*	22.1
lg(Day-ahead mid-term load forecast error)	-0.19	0.13	-0.22	0.14	13.1	16.5	12.7	15.4
Minimum generation event	0.05	0.09	0.03	0.08	25.6**	5.1	24.7**	5.6
lg(Transmission outage)	0.13	0.11	0.21*	0.10	3.2	11.0	4.9	11.2
Constant	14.27	2.43	12.65	2.35	419.4	239.2	383.4	188.8
R^2	0.6814		0.6493		0.3779		0.3753	



Case Study - Texas

- Largest wind producer in the U.S.
- 39.4 GWh in 2014
- 22% of national wind energy
- Over 10% of Texas electricity

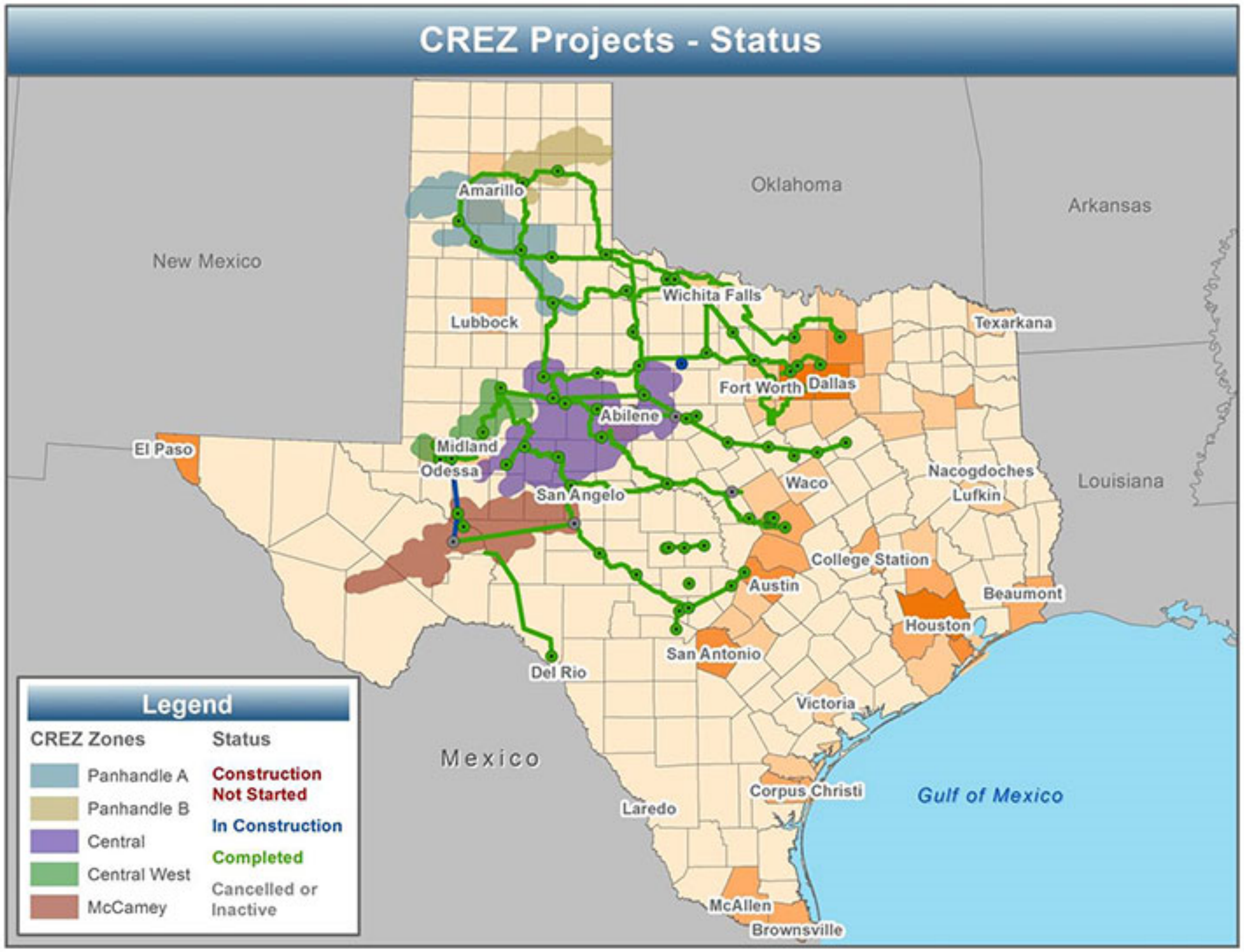


Chart by EIA

Fewer wind curtailments and negative prices after grid expansion

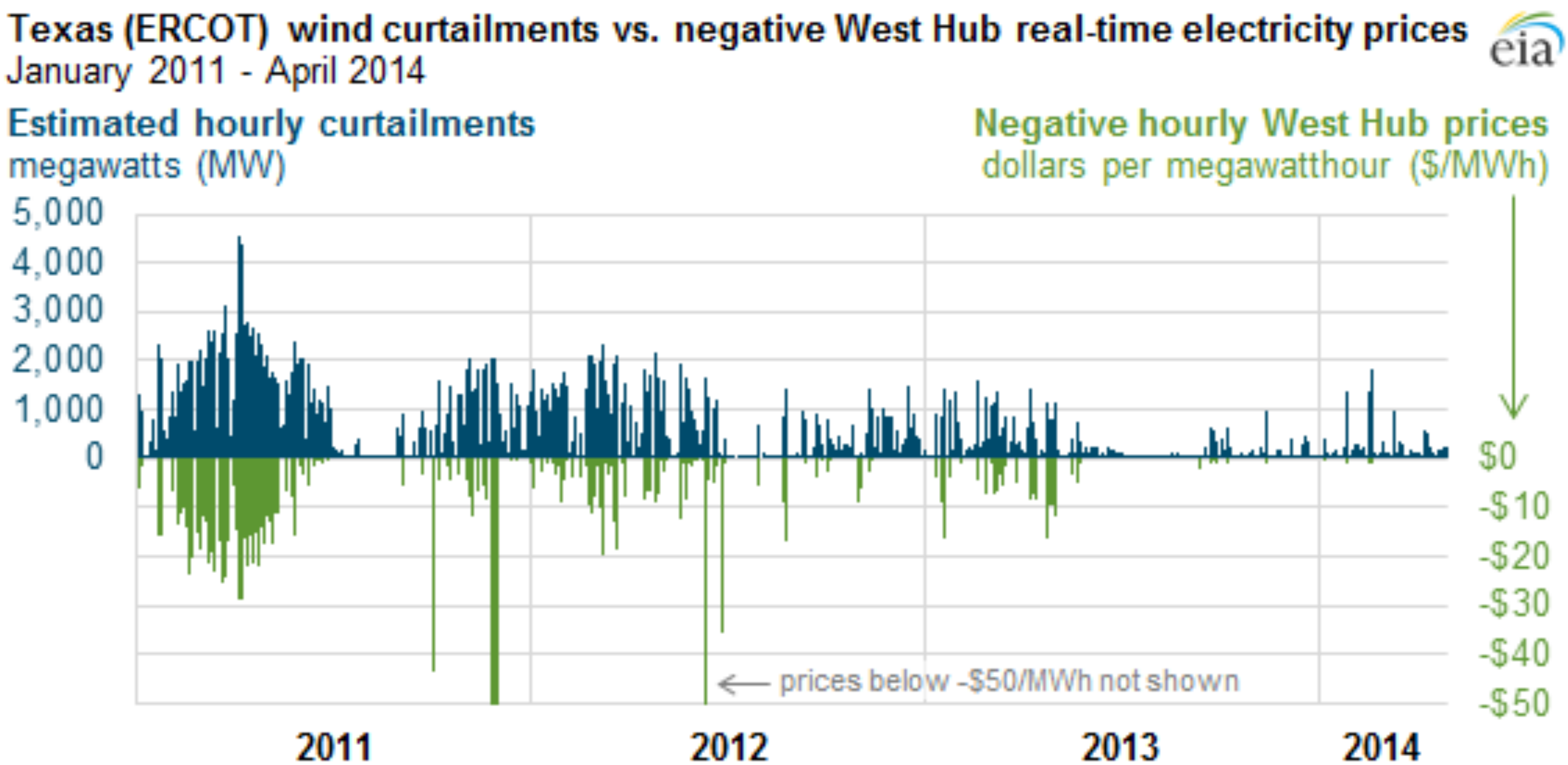


Chart by EIA

Case Study – Iowa Lakers Electric Cooperative

- Iowa is the 2nd largest wind producer in the U.S.
- Iowa Lakes Electric is a non-profit distribution-only coop
- Owns 14 wind turbines with a total capacity of 21 MW
- The biggest installed wind capacity of any U.S. distribution-only coop

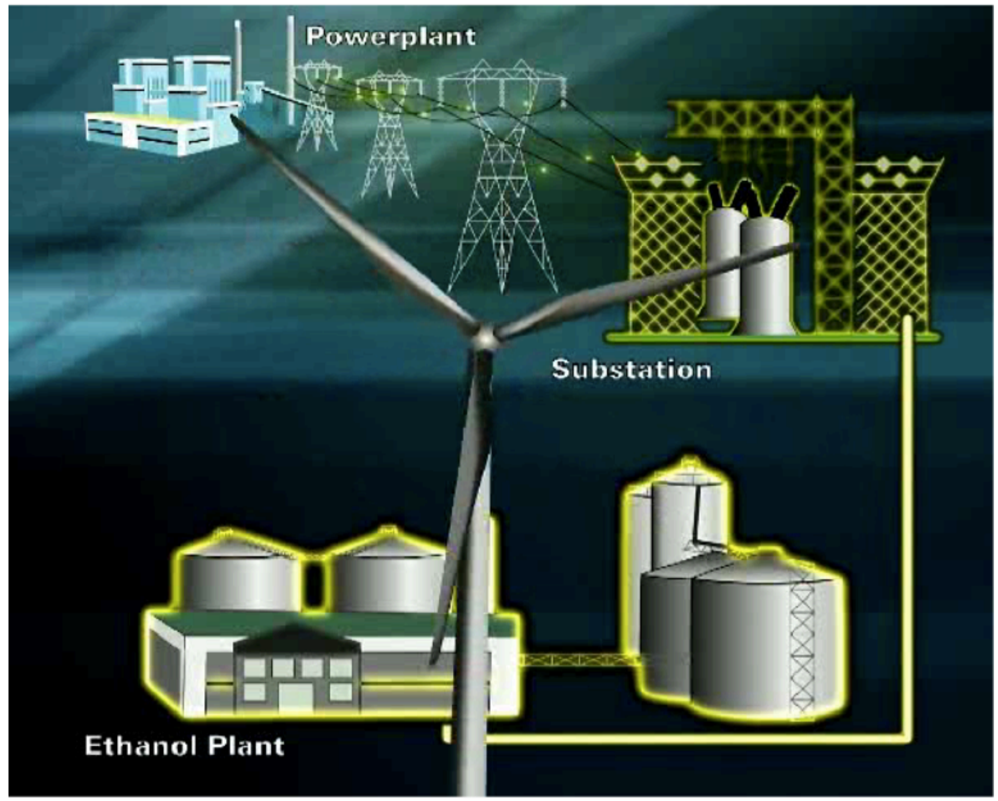


Chart by Iowa Lakers Electric Coop

Case Study – Germany's energy storage

- Germany is the largest wind energy producer in Europe with 50.670 TWh electricity and 31,331.9 MW installed wind power net capacity
- *Huntorf compressed air energy storage plant (CASE)*
- CASE is the world's first and still largest utility-scale compressed air storage plant
- Capacity: 321 MW
- Short rump up time - 6 minutes

Conclusions

- Current data is rather limited in estimating PTC’s impact on negative prices
- Negative pricing hours are positively correlated with load forecast errors and minimum generation events
- Case studies of high wind penetration regions suggest solutions for better wind integration: transmission expansion, efficient siting close to local demand centers, and energy storage