

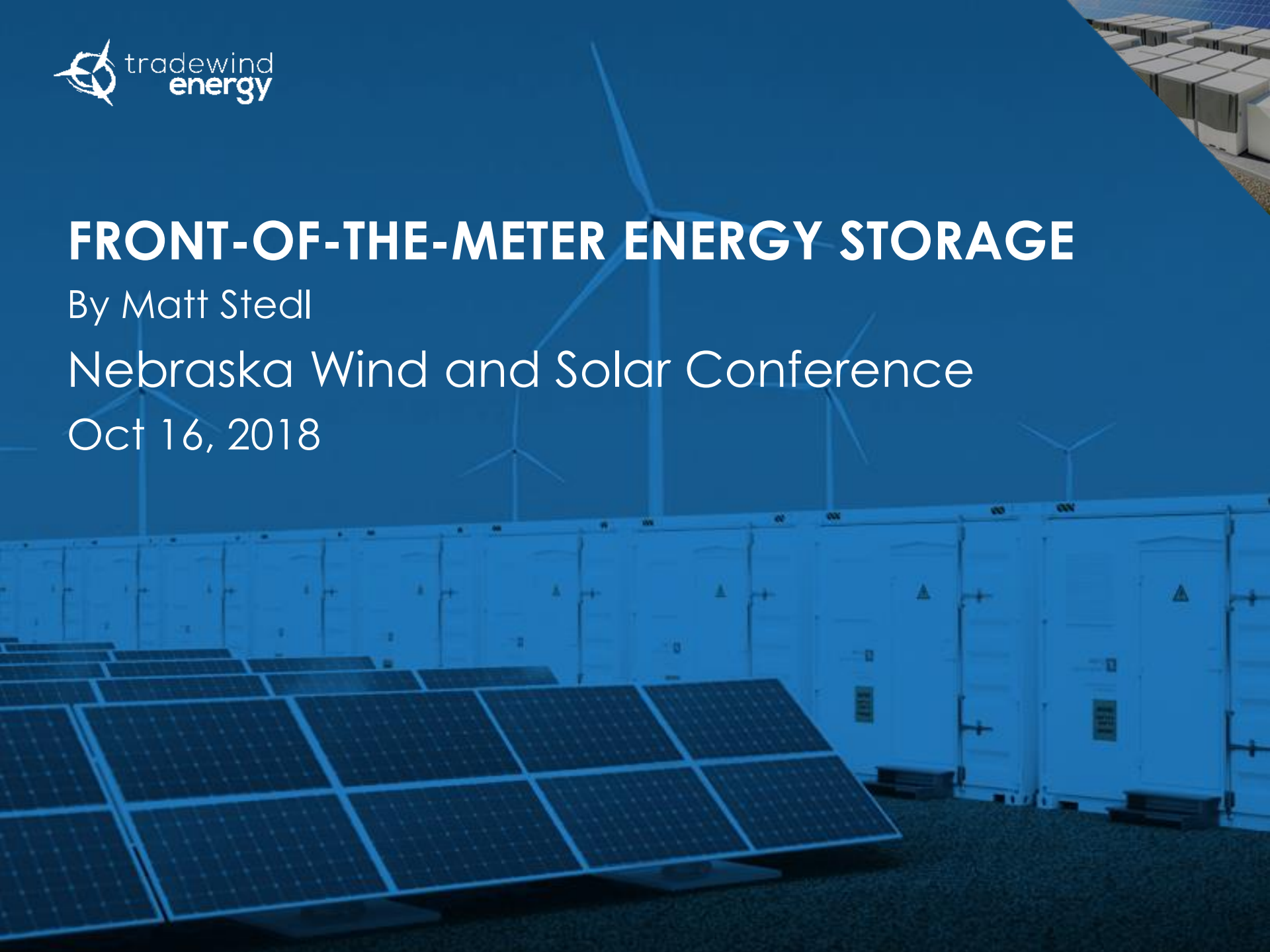


FRONT-OF-THE-METER ENERGY STORAGE

By Matt Stedl

Nebraska Wind and Solar Conference

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Among the Largest & Most Successful Wind, Solar, and Storage Development Companies in the U.S.

- **Company Info**

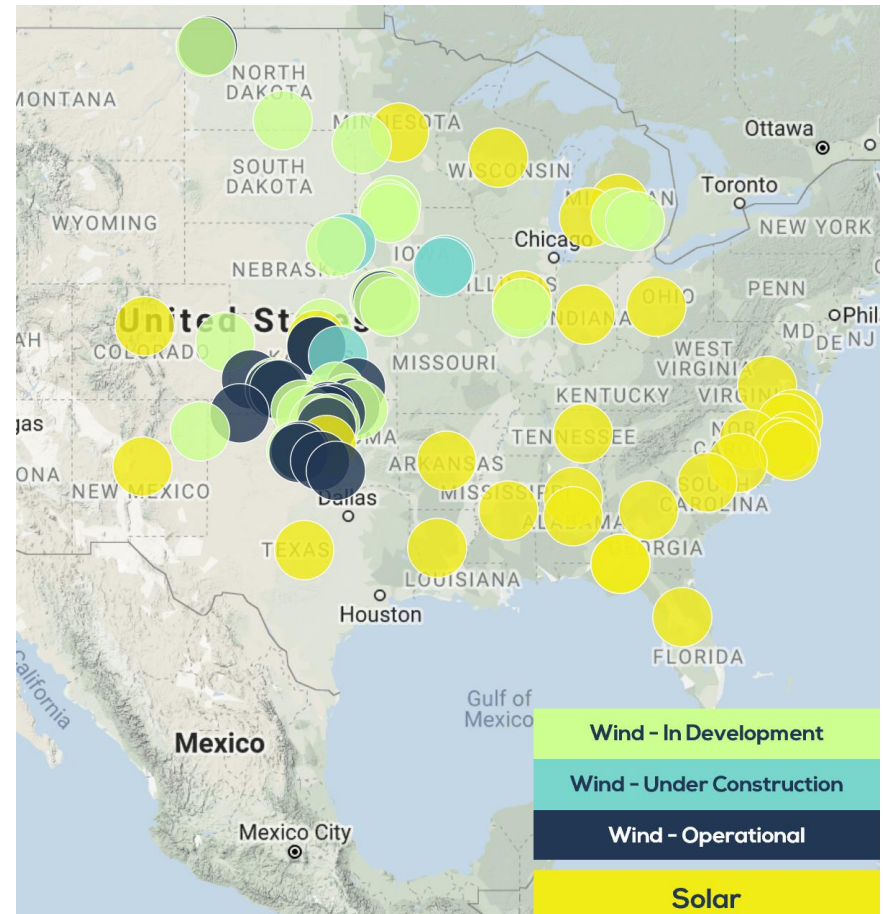
- Founded in 2002
- Headquarters in Lenexa, KS
- 140+ full time employees

- **Current Development Portfolio**

- Present in more than 25 states
- #1 US Wind Developer in 2017
- **More than 8 GW of wind assets**
- **More than 3 GW of solar assets**
- **More than 1 GW of storage assets**

- **Tradewind Success**

- **3 GW+ contracted & operating projects**
- Successes total more than \$5 Billion capital investments





- 1. Front-of-the-Meter (FTM) Energy Storage Applications**
- 2. FTM Energy Storage Configurations**
- 3. Wind + Storage**
- 4. Current FTM Challenges**



1. Energy Time Shift: Load during times of excess/inexpensive generation, Generator at peak load times
2. Provide Firm Capacity to non-firm solar and wind projects
3. Act as a Shock Absorber to the system
 - Frequency Regulation (fast response)
4. Transmission and Distribution deferral
5. Provide Backup Power during grid outage?



IN DECREASING ORDER OF MARKET VALUE*

1. **Frequency Regulation**
2. **Capacity Value (or “Resource Adequacy”)**
3. **Transmission Deferral**
4. **Distribution Deferral**
5. **Spinning Reserve**
6. **Energy Arbitrage (buy low, sell high)**
7. **Voltage Support / Blackstart**

*Market Values are highly location-dependent, this is a representative list of market values based on the higher end of projected values



- **Stand-Alone Storage** - Wholesale “Generator” & “Load”:
- **Stand-Alone Storage** - Transmission and/or Distribution Asset
- **Stand-Alone Storage** - Transmission / Distribution Asset AND Wholesale Generator/Load??
- **Wind + Storage** - Co-located with Wind
- **Solar + Storage** - Co-located w/Solar
- **Other** (Gas + Storage, Compressed Air, Pumped Hydro, ...)



- Energy Arbitrage: buy low, sell high (on-wind vs. off wind)
- Firm Capacity Value (Wind-Only ~10-15% capacity credit)
- FR/Ancillary services
- NOT ITC eligibility (typically)
- Curtailment abatement (charge from wind during curtailment/negative pricing events)
- Ramp Rate Control (no rapid cut-out)
- Bulk Storage options (long duration storage)
- LOWEST \$/MWh (PSCO RFP: ~\$21/MWh for wind + storage vs. ~\$36/MWh for Solar + Storage) (note: storage duration not included in PSCO median price report)



Below Table is for the Storage Portion of the Facility

| | Wind + Storage | Solar + Storage | Stand-Alone Storage |
|-------------------------------------|-----------------|--|---------------------|
| ITC Eligible | NO | YES (must charge from solar for first 5 years) | NO |
| Can Charge from the Grid? | YES | NO (1st 5 years) , YES Years 6+ | YES |
| Earn Frequency Regulation Revenues? | YES | NO (1st 5 years) , YES Years 6+ | YES |
| Shared interconnection facilities | YES | YES | NO |
| Charging Cost | LOW (overnight) | MEDIUM (PPA for 1st 5 year) | LOW (overnight) |

Take-Aways:

1. Wind + Storage is best option to charge at night, or manage on-wind vs off-wind generation, and to be able to generate ancillary service FR revenues
2. Wind + Storage is best option for lowest cost dispatchable \$/MWh for renewable system (assuming 2020 COD for wind/ full PTC).
3. Solar + Storage is the best option for lowest capacity cost \$/kW-mo, with marginally higher energy dispatch / charging costs and charging limitations/ no FR during first 5 years.
4. Stand-Alone Storage is the best option when location matters most (and T&D deferral).



1. **Market Participation** (FERC Order 841 to address)
2. **Interconnection Process** (FERC Order 845 to address)
3. **Proper compensation** for value provided to system (FERC Order 841 to address)
4. **Lack of predictable cash flow** (State mandates/procurements helping a lot)



- Remove barriers to participation of Electric Storage resources
- Ensure Storage eligibility to participate in market if “technically capable” (Energy, Capacity, and Ancillary Services)
- Ensure dispatchable Storage Resources can set price
- Account for physical and operational characteristics through bidding

Compliance Filings due from ISOs:

Dec 3, 2018

Final ISO Changes in effect:

Dec 3, 2019



- Recognizes energy storage as a resource in its own right — rather than requiring storage to conform to rules designed for generators
- The order will allow interconnection agreements to be tailored to the level of service requested, which can be lower than nameplate capacity
- Expedited (i.e., non-queued) process to interconnect new facilities with existing generators that aren't using all their capacity all the time
- Previously, a 50 MW generator and a 25 MW storage device would be studied as a 75 MW facility for reliability purposes. But Order 845 allows the facility to be studied as the original 50 MW generator as long it does not exceed 50 MW

Compliance Filings due from ISOs:

Extended Indefinitely

Final ISO LGIP Changes in effect:

???





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