GOALS OF THIS WEBINAR

1. Basic understanding of power markets
2. Electricity is a tradable commodity
3. Growing impact of congestion on the grid
ELECTRICITY IS A COMMODITY
COMMODITIES: CRUDE OIL

Production

Deepwater Rig - Transocean

Transportation

Crude tanker - DHT Holdings

Consumption

Crude refinery - ExxonMobil
COMMODITIES: NATURAL GAS

Production
Fracking Rig - Pennsylvania - Cabot Oil & Gas

Transportation
Nexus Pipeline - Ohio - DTE Energy

Consumption
Residential meter - New England - National Grid
COMMODITIES: ELECTRICITY

Production
Notrees Wind Farm - West Texas - Duke Energy

Transportation
138 kV line - Central Texas - ONCOR

Consumption
City of Houston - East Texas - Houston Chronicle
THE GRID:
REGULATED VS Deregulated
THE TRANSMISSION GRID

1. Regulated Markets

2. Deregulated Markets

Duke Nicholas School
DEREGULATED REGIONS

1. Grid stability
2. Cost efficiency
DAY-AHEAD MARKET

Holman - 50 MW - Engie - ERCOT

Ocotillo - 265 MW - CAISO

Stanislaus - 265 MW - NCPA - CAISO

Kendal Cogen - 256 MW - ISONE

Fort Sammis - 1,000 MW - PJM

Liquifaction Terminal - 600 MW - ERCOT

Electric Cooperative - 4,000 MW - SPP

PG&E

BASIN ELECTRIC POWER COOPERATIVE

TXU Energy

SARACEN

Morgan Stanley

Spec Shop/Market Maker

Spec Shop

ISO

Hedge Fund

Market Maker

ISO

Retailer - ERCOT

Utility - 20,000 MW - CAISO
DAY-AHEAD DEADLINES

- New York ISO (Independent System Operator): 5:00 AM EST
- SPP (Southwest Power Pool): 9:30 AM CST
- CAISO: 10:00 AM PST
- MISO: 10:30 AM EST
- PJM: 10:30 AM EST
- ERCOT: 10:00 AM CST
- ISO New England: 10:00 AM EST
DAY-AHEAD MARKET

- Physical Supply
- Financial/Virtual Supply & Demand
- Physical Demand

ISO

$26.45\ MW
WHERE ELSE CAN YOU BUY & SELL POWER?
TRADING ON ICE
PRODUCTS ON ICE

<table>
<thead>
<tr>
<th>Product</th>
<th>V</th>
<th>Hub</th>
<th>V</th>
<th>Strip</th>
<th>V</th>
<th>End Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Futures</td>
<td></td>
<td>ERCOT North 345kV Hub RT</td>
<td></td>
<td>HE 9700-HE 2200</td>
<td></td>
<td>March 28</td>
</tr>
<tr>
<td>Peak Futures</td>
<td></td>
<td>ERCOT North 345kV Hub RT</td>
<td></td>
<td>Next Day</td>
<td></td>
<td>March 28</td>
</tr>
<tr>
<td>Peak Futures</td>
<td></td>
<td>ERCOT North 345kV Hub RT (16 MW)</td>
<td></td>
<td>HE 9700-HE 2200</td>
<td></td>
<td>March 28</td>
</tr>
<tr>
<td>Peak Futures</td>
<td></td>
<td>ERCOT North 345kV Hub RT (16 MW)</td>
<td></td>
<td>Next Day</td>
<td></td>
<td>March 28</td>
</tr>
<tr>
<td>Peak Futures</td>
<td></td>
<td>ERCOT North 345kV Hub RT (16 MW)</td>
<td></td>
<td>Bai Week</td>
<td></td>
<td>March 28</td>
</tr>
<tr>
<td>Peak Futures</td>
<td></td>
<td>ERCOT North 345kV Hub RT (16 MW)</td>
<td></td>
<td>Custom X 16</td>
<td></td>
<td>March 28</td>
</tr>
<tr>
<td>Peak Futures</td>
<td></td>
<td>ERCOT North 345kV Hub RT (16 MW)</td>
<td></td>
<td>HE 9700-HE 2200</td>
<td></td>
<td>March 28</td>
</tr>
<tr>
<td>Peak Futures</td>
<td></td>
<td>ERCOT North 345kV Hub RT (16 MW)</td>
<td></td>
<td>HE 9700-HE 2200</td>
<td></td>
<td>March 28</td>
</tr>
</tbody>
</table>

Additional columns include: Price, Offer, Buy/Limit, Last, Hi Low, Volume, Block Vol, Bid, Offer, O_Cqy.
BILATERAL TRADES

Retail Load

Generation (gas, coal, nuclear)

Industrial Load

Generation (gas, wind)
WHAT DRIVES PRICE MOVEMENT?
PRICE DRIVERS

Henry Hub Spot Price

- Polar Vortex
- Bombogenesis

PJM West Hub Real-time Price

- Polar Vortex
- Bombogenesis

Polar Vortex - January 2014
**Price Drivers**

- Wind driven pricing
  - MISO
  - SPP
  - ERCOT
PRICE DRIVERS

**Solar** driven pricing
- CAISO
- NEPOOL
• October of 2017
  • Luminant announces 4,200 MW of coal retirements

Source: Bloomberg
GOALS OF THIS WEBINAR

1. Basic understanding of power markets
2. Electricity is a tradable commodity
3. Growing impact of congestion on the grid
CONGESTION
Grid congestion occurs due to transmission constraints – a lack of transmission line capacity to deliver electricity without exceeding thermal, voltage and stability” - NRG

Production
Notrees Wind Farm - West Texas - Duke Energy

Transportation
138 kV line - Central Texas - ONCOR

Consumption
City of Houston - East Texas - Houston Chronicle

153 MW ► 145 MW ► 20,000 MW
• Line is “overloading”
• Solution?
CONGESTION
CONGESTION
Products

Daily
• Point-to-Points (PTP)
• Up-to-congestion (UTC)

Monthly
• Congestion Revenue Rights (CRR)
• Financial Transmission Rights (FTR)
• Transmission Capacity Rights (TCR)

Annual
• CRR, FTR, TCR
TRADING CONGESTION

Source vs Sink

Futures Market vs Spot Market

Day-ahead vs Real-time
CASE STUDIES
SPINNING SPUR
CASE STUDY: SPINNING SPUR

- ISO: ERCOT
- Owner: EDF Renewables
- Capacity: 516 MWs
- Fuel: Wind
- Power Purchase Agreement (PPA) with Southwestern Public Service Company

Spinning Spur

Genscape
CASE STUDY: SPINNING SPUR

Energy Sold on April 23rd for April 24th 2019

Actual Generation on April 24th 2019
CASE STUDY: SPINNING SPUR

- Power Purchase Agreement (PPA) w/ Southwestern Public Service Company
- Wind forecast?
- Why still produce?
CASE STUDY: SPINNING SPUR

Problem of the PPA

- Power Purchase Agreement (PPA) w/ Southwestern Public Service Company
- West Hub?

Solution?

- HEDGE!
- PTP (Day-ahead vs Real-time)
- CRR (Next-month vs Day-ahead)
MAGIC VALLEY
CASE STUDY: MAGIC VALLEY

Magic Valley Generating Station

- ISO: ERCOT
- Owner: Calpine
- Capacity: 682 MWs
- Fuel: Natural Gas
- Power Purchase Agreement (PPA) w/ Magic Valley Electric Coop
CASE STUDY: MAGIC VALLEY

Energy Sold on Oct 5th for Oct. 6th 2019

Actual Generation on Oct. 6th 2019 (MWs)

Nedin345/1 kV transformer “overloads”
CASE STUDY: MAGIC VALLEY

- Power Purchase Agreement (PPA) w/ Magic Valley Electric Coop
- Buy power in spot market?
IMPERIAL VALLEY
CASE STUDY: IMPERIAL VALLEY

Imperial Valley

- ISO: CAISO
- Owner: Tenaska
- Capacity: 150 MWs
- Fuel: Solar
- Power Purchase Agreement (PPA) w/ San Diego Gas & Electric

![Map of California showing Imperial Valley with a red star indicating the location.](Image)
CASE STUDY: IMPERIAL VALLEY
CASE STUDY: IMPERIAL VALLEY

Transmission line maintenance
East County – Miguel 500 kV line
March 23rd to March 26th
CASE STUDY: IMPERIAL VALLEY

- Power re-routed
- Parallel equipment “overloads”

Congestion on the Suncrest 500/230 kV transformer
CASE STUDY: IMPERIAL VALLEY

Without transmission outage

With transmission outage

Curtailed MWs
Case Study: Imperial Valley

Problem of the PPA

- Power Purchase Agreement (PPA) w/ San Diego Gas & Electric
- SP15 Hub?

Solution?

- HEDGE?
- PTP? Not available in CAISO.
- CRR (Next-month vs Day-ahead)
THE PERMIAN BASIN
CASE STUDY: THE PERMIAN BASIN
CASE STUDY: THE PERMIAN BASIN

- 69 kV lines ✓
- 138 kV lines ✓
- 345 kV lines ❌
CASE STUDY: THE PERMIAN BASIN

Load driven congestion
CASE STUDY: THE PERMIAN BASIN

**Solutions?**

- Notrees Battery (36 MW)
- Flat Top Battery (9.9 MW)
- Worsham Battery (9.9 MW)
GOALS OF THIS WEBINAR

1. Basic understanding of power markets
2. Electricity is a tradable commodity
3. Growing impact of congestion on the grid