Seven Technology Disruptions Behind the Energy Transition

Understanding the Structural Decline of the U.S. Coal Industry

Seth Feaster, Energy Data Analyst, IEEFA

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World Consumption of Coal …
Last year, China consumed more than half of all the coal the world used. India, the United States, and Europe accounted for another quarter.

… and Share Consumed for Electricity
Over 90 percent of the coal used in the United States was used to produce electricity; that share was far lower among the biggest consumers in Asia.

Estimates for 2017
- China: 54.1%
- United States: 8.8%
- India: 9.3%
- Europe (OECD countries): 7.6%
- Japan: 2.6%
- Russia: 2.5%
- S. Korea: 1.9%
- Rest of the world: 13.2%

Figures for 2015
- China: 53%
- United States: 92%
- India: 67%
- Germany: 81%
- Poland: 71%
- United Kingdom: 76%
- Japan: 60%
- Russia: 57%
- S. Korea: 69%

Sources: Energy Information Administration (consumption); International Energy Agency
Coal’s share as a fuel for electricity generation has fallen sharply over the last 15 years as natural gas, wind, and solar have gained market share. Hydro and nuclear have remained relatively unchanged over the same period.

Source: Energy Information Administration *Utility-scale only
The Seven Disruptions of the Energy Transition

**GENERATION**
- Energy Efficiency
  - Policy/Technology disruption
- Wind
  - Semiconductor/Manufacturing/Construction disruption
- Solar
  - Mechanical/Industrial Construction disruption
- Fracking
  - Mining Extraction/Industrial Technology disruption

**GRID**
- Grid Integration
  - Software/Information Technology disruption
- Grid Independence
  - Equipment Scale/Business Model disruption
- Energy Storage
  - Electrochemical Engineering/Business Model disruption
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U.S. Net Generation of Electricity, 1950-2017

Decades of growth in electricity use ended in 2007, and demand has been flat to down ever since.

4,000 million megawatt hours

2007: Peak Generation
4,157 mil. MW hours

Source: Energy Information Administration
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Wind and solar generation has been growing relentlessly as costs for these renewables have fallen sharply; grid operators have mastered integrating them; and utilities have increasingly embraced them.

Source: Energy Information Administration

Note: Share of generation for all sectors
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**GRID**
U.S. Natural Gas Production, 1985-2017

After about a decade of flat natural gas production (1995-2005), rapid adoption and technical advances in the use of hydraulic fracturing in shale formations led to a surge in supply and low prices.

Dec. 2017 2.994 trillion

Shale Gas Production
Monthly average each year

2016 1.419 trillion

2006 0.108 trillion

Source: Energy Information Administration
U.S. solar projects:
Cost of power-purchase agreements vs. natural gas combined cycle

Source: GTM Research
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Wind farm

Texas-Oklahoma, August 2018
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Wind and Solar Share of U.S. Electricity Generation

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**Equipment Scale/Business Model disruption**
- Mining Extraction/Industrial Technology disruption
- Mechanical/Industrial Construction disruption
Peaking Gas Combustion Turbine vs. 4-Hour Li-Ion Battery Storage ($/MWh)

Source: GTM Research, Wood Mackenzie
General grid-operator rules:

1. No blackouts
2. “Cost effective” operation

Demand curve

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<tr>
<th>POWER DEMAND</th>
<th>TIME OF DAY</th>
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<td>POTENTIAL PEAK</td>
<td>ACTUAL PEAK</td>
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Types of generation

- RESERVES
- VARIABLE LOAD
- BASE LOAD

Traditional dispatch stack

- HIGHEST COST
  - Diesel, Oil
  - Oldest Coal
- LOWEST COST
  - Natural gas
  - Coal
  - Nuclear
  - Hydro
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<th>COST RANGE</th>
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<tr>
<td>UP TO $9,000 MEGAWATT HOUR (TEXAS)</td>
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<td>GENERALLY $20 – $50 MEGAWATT HOUR</td>
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<td>$0 DURING MAXIMUM SOLAR GENERATION (CALIFORNIA)</td>
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<td>HIGHEST COST</td>
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<td>Solar or wind + batteries</td>
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<td>Coal</td>
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<tr>
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Implications for the U.S. Coal Industry

1. Technology-driven, disruptive economics arrayed against coal are broad and long-term

2. Coal industry innovations are limited, with some notable recent failures

3. Intellectual and financial capital avoiding coal

4. Competitive intensity accelerating, compounded by social and business embrace of new technologies
Outcomes for the U.S. Coal Industry

1. No new coal plants
2. Existing plants see accelerated retirements due to age and economic competition
3. Federal policy changes have minimal impact on pace of closures and long-term planning by utilities
4. Non-export mining companies face relentless financial distress and financial extraction
5. Mine closures coming
EIA Coal Consumption Forecasts, 2006-2018

Each year, the Energy Information Administration releases its Annual Energy Outlook, which includes a long-term forecast for U.S. coal consumption for electric power generation. However, the forecasts have been wildly inaccurate, even in the near term.

Source: Energy Information Administration