

# DISRUPTOR or DISRUPTEE

The Evolving Role of Natural Gas in Electricity

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Department of Energy

# INTRODUCTION

## Take Home Messages

## **Poor Prediction Performance**

Telling the future is a risky business

## **Natural Gas is an Adaptor**

History provides a guide

## **Paths Diverge in a Wood**

And other Frostian wisdom

**INTERACTIVE POLL**



**What is the furthest planning horizon in your organization?**

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PRESENT

**The history of predictions has been hazy**

Electricity  
Load

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Load growth has consistently underperformed expectations

Technology Prices and  
Adoption

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New technologies have advanced faster or slower than anticipated

Fuel Prices

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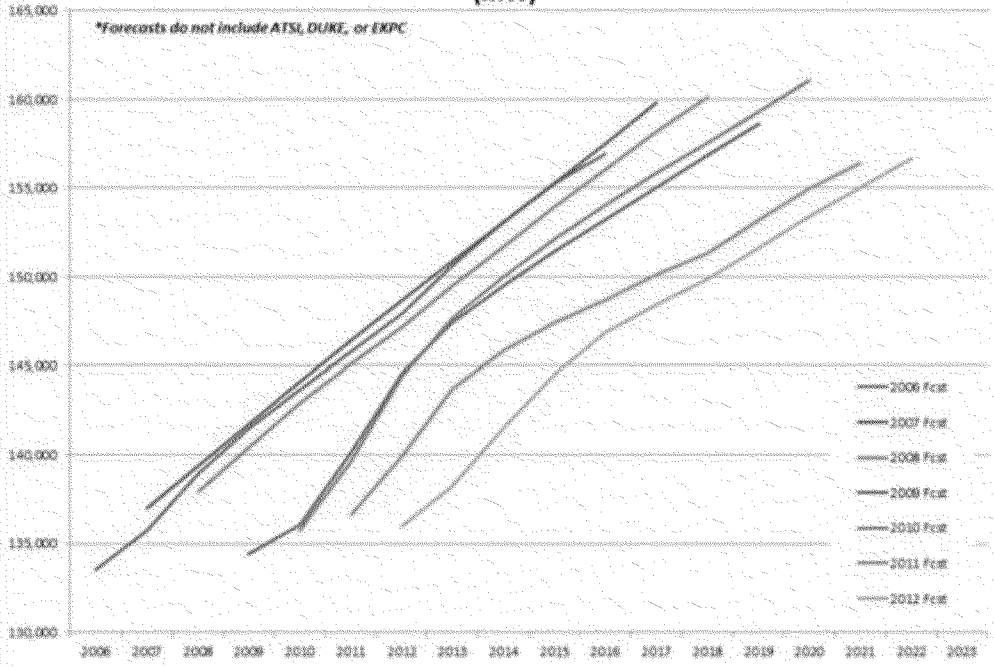
If you wait long enough, chances are you'll eventually be right

# Load PJM

“Beginning with the Great Recession of 2007-2009, the accuracy of the PJM model decayed noticeably, with a trend towards over forecasting.”

### PJM RTO\* Summer Peak Forecasts (MW)

\*Forecasts do not include ATSI, DUKE, or EKPC



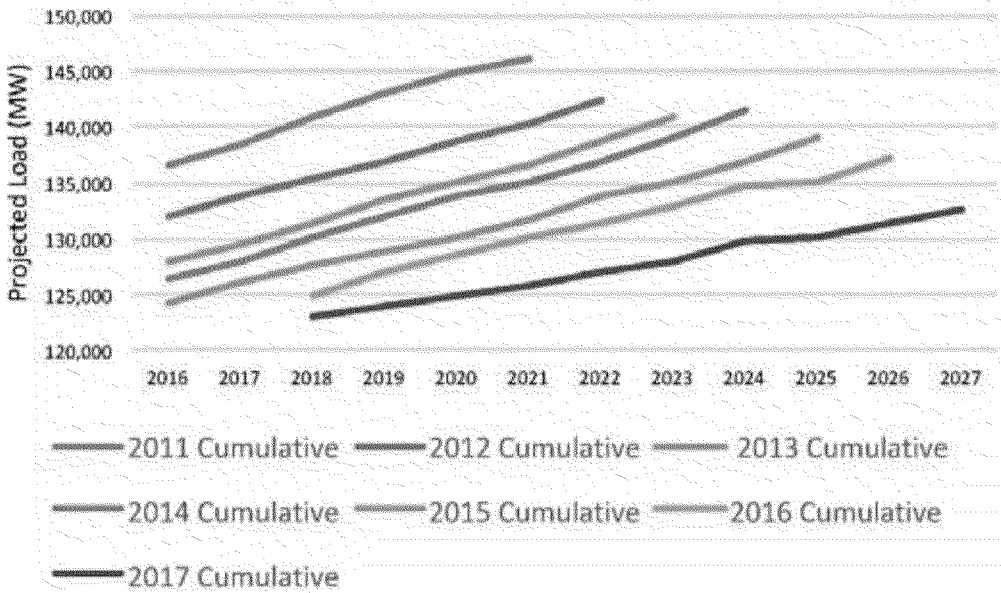
Source: PJM Resource Adequacy Planning Department "Load Forecasting Model Whitepaper," April 27, 2016

# Load Southeast

"...one does have to ask, how did they get it so wrong?"

### SERTP Region - Cumulative Summer Peak Load Forecast

Source: SERTP

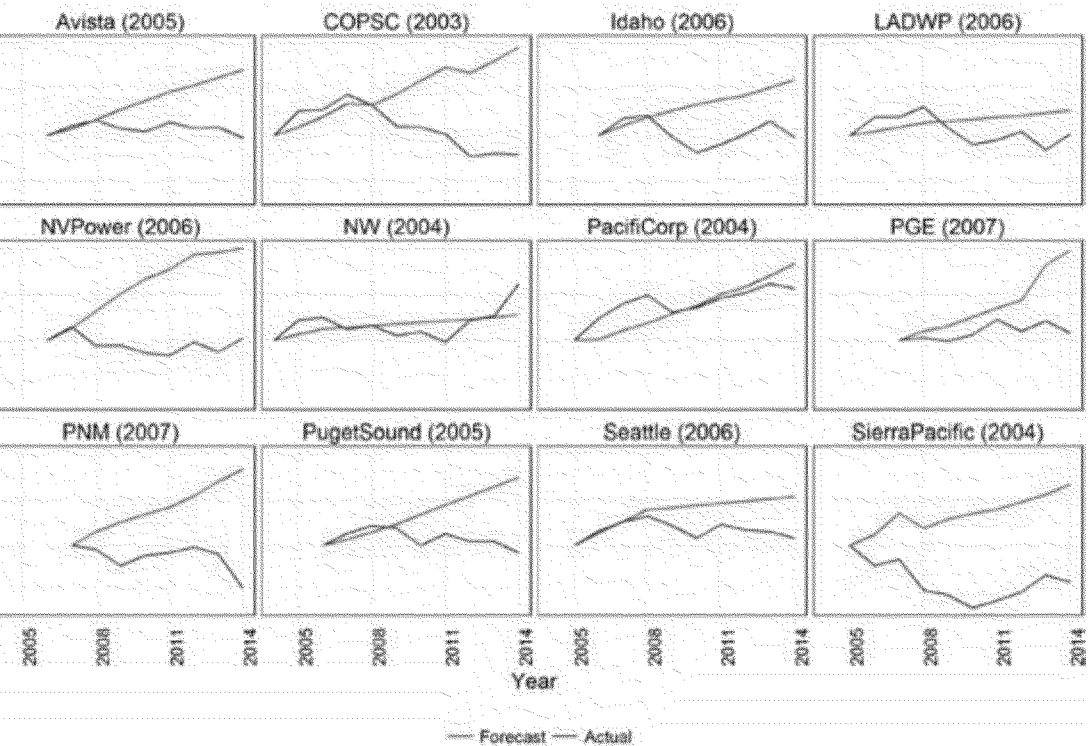


Source: C Three, "North American Electric Transmission Market Forecast," August 2017

# Load West

"...there continued to be a systematic over estimation of load growth rates..."



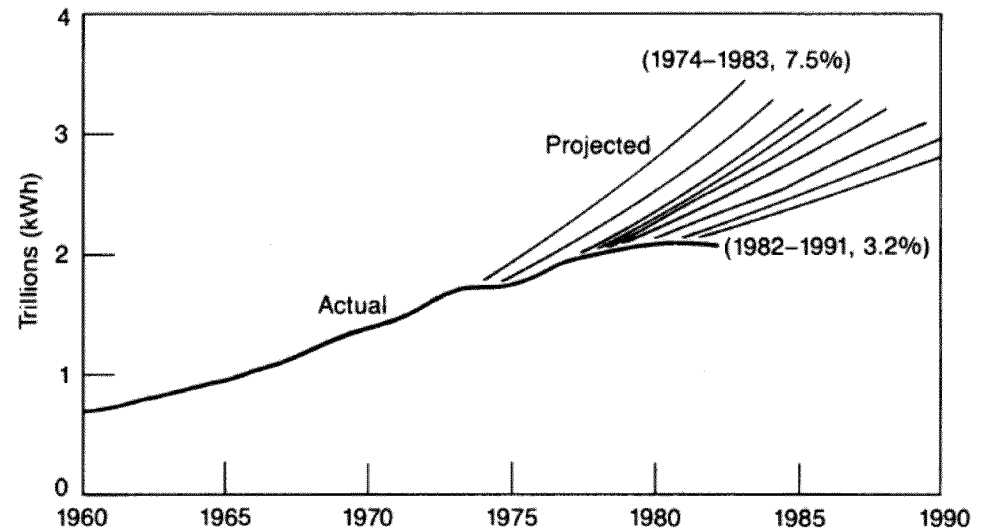


Source: Juan Pablo Carvalho, Peter H. Larsen, Alan H. Sanstad, Charles A. Goldman, "Load Forecasting in Electric Utility Integrated Resource Planning," October 2016, LBNL- 1006395

# Load National

"All forecasts are wrong. ...A more realistic expectation, especially for long term forecasts, is the insights on the various risks that may confront a utility."

NERC Fan: Actual (1960-1982) and Projected (1974-1990)



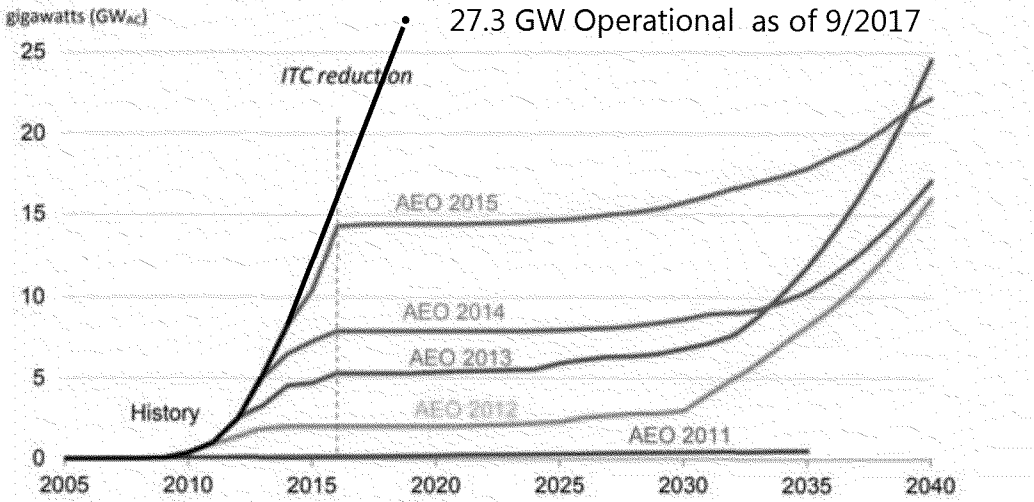
Source: Tao Hong, Mohammad Shahidehpour, "Load Forecasting Case Study," January 15, 2015

# Technology

## Solar

“These [projections] largely missed the rapid build out of utility scale solar PV projects.”

Figure A-10. Utility-Scale solar PV capacity projections in AEO 2011 to 2015 Reference cases, 2005-2040



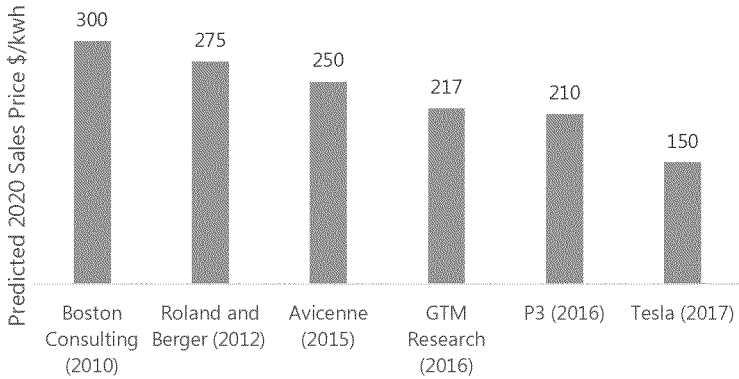
Sources: EIA, Annual Energy Outlook 2011–2015 editions.

Sources: EIA, "Wind and Solar Data and Projections from the U.S. Energy Information Administration: Past Performance and Ongoing Enhancements," March 2016  
 Colin Smith, "U.S. Utility PV Market: Quarterly Update," GTM Research, September 2017

# Technology Storage

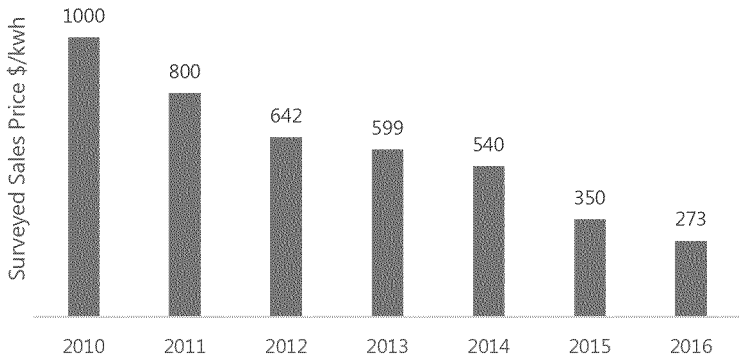
“Updated data that indicate lower battery costs have increased EIA’s outlook for BEV and PHEV sales.”  
EIA AEO 2017

## Li-Ion Battery 2020 Sales Price Predictions



Source: Berckmans et al., "Cost Projection of State of the Art Lithium-Ion Batteries for Electric Vehicles Up to 2030," *Energies* 2017, 10, 1314; doi:10.3390/en10091314

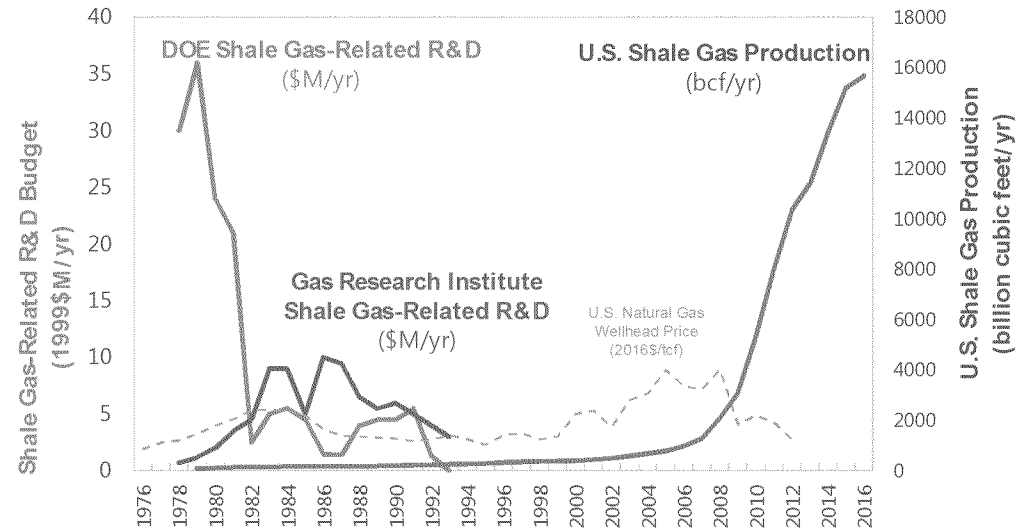
## BNEF Li-ion Battery Price Survey



Source: Clare Curry, "Lithium-ion Battery Costs and Market," *Bloomberg New Energy Finance*, July 5, 2017

# Technology Shale Gas Production

"...the convergence of a number of factors, including key technology developments, government policy, and market forces, coalesced to bring about the shale gas revolution."



Technology	Level of DOE Influence
Fracture technology for tight gas	Influential
Improved oil and gas drilling: horizontal, deviated, and extended	Absent/Minimal
3-D seismic imaging	Absent/Minimal
Diamond drill bits	Direct

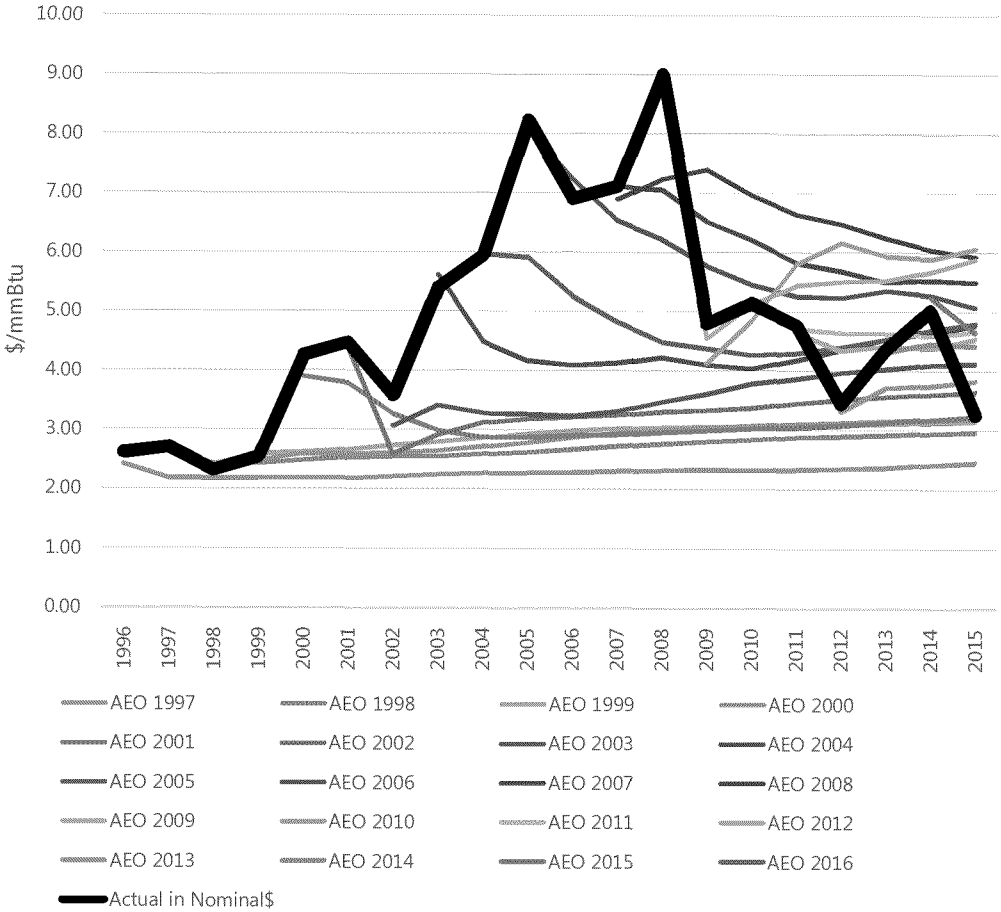
Source: Robert Homer, "Federal Government Contributions to the Shale Gas Revolution," DOE/EPISA Internal Memo, June 14, 2017

# Fuel

## Natural Gas Prices

"...the absolute percent differences [between the AEO projections and realized outcomes] for energy prices range between 10% and 40%."

## EIA Actual vs Projected Natural Gas Prices

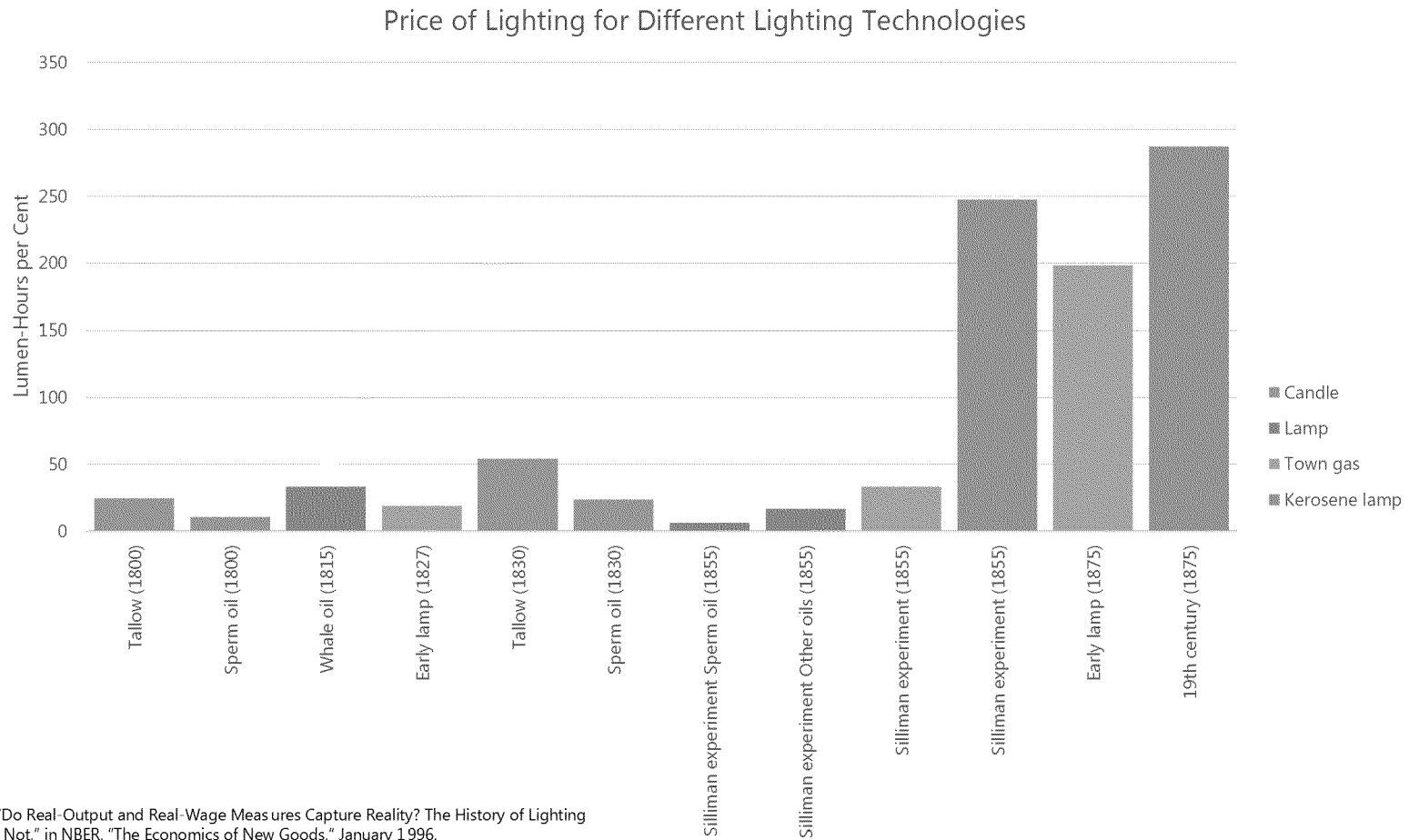


Source: EIA, "Annual Energy Outlook Retrospective Review, Table 7a," September 19, 2017



# Light

## Improvements in lighting value over time



# 1870s

## Natural Gas as Disruptee

• "Virtually all manufactured gas sold during this period was used for lighting." - Troesken

1870s

1878

• "Even before Edison demonstrated a working lamp, gas stocks began to fall in price." - Smithsonian

1879

• Edison lighting demonstration at Menlo Park

1882

• Pearl Street Station opens

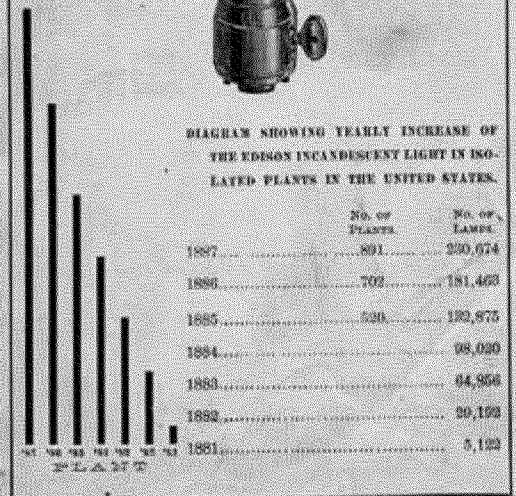
Sources: Werner Troesken, "The Institutional Antecedents of State Utility Regulation: The Chicago Gas Industry, 1860 to 1913," in NBER, "The Regulated Economy: A Historical Approach to Political Economy," January 1994  
Smithsonian Institution, "Lighting A Revolution," May 2017, <http://americanhistory.si.edu/lighting/19thcent/comp19.htm>, Accessed 11/1/2017  
Image from Richard Warren Lipack / Wikimedia Commons. [http://ethw.org/Edison%27s\\_Electric\\_Light\\_and\\_Power\\_System](http://ethw.org/Edison%27s_Electric_Light_and_Power_System)

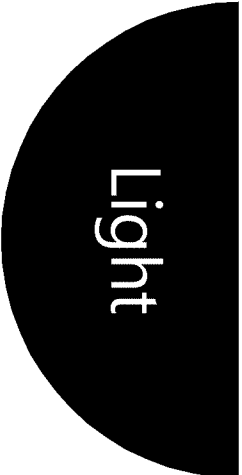
The Edison United  
Manufacturing Company,

65 FIFTH AVENUE,  
NEW YORK.



NO. 1 A  
PITTSBURGH, PA.

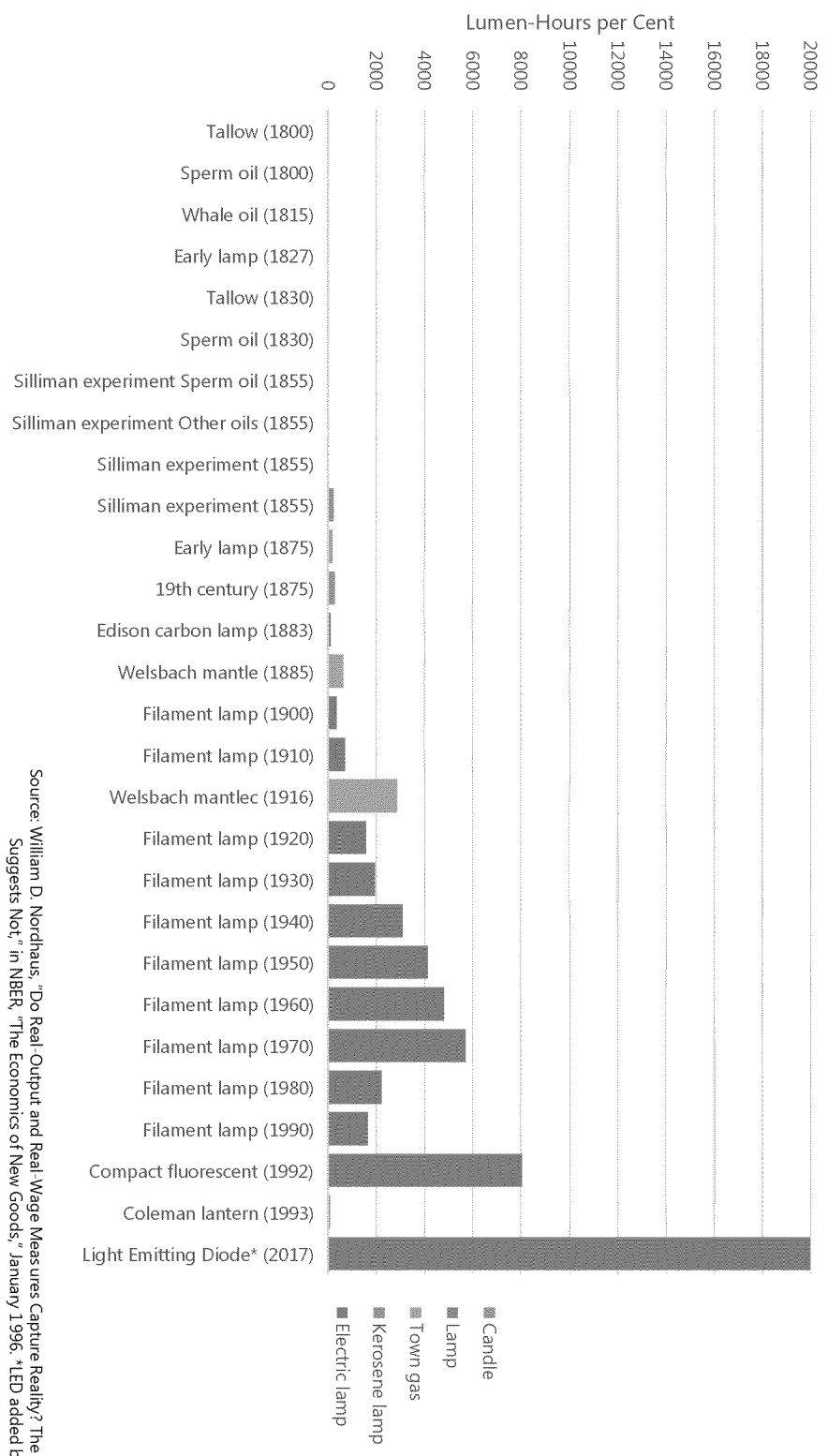




# Light

## Improvements in lighting value over time

Price of Lighting for Different Lighting Technologies



Source: William D. Nordhaus, "Do Real-Output and Real-Wage Measures Capture Reality? The History of Lighting Suggests Not," in NBER, "The Economics of New Goods," January 1996. \*LED added by author.



*"It was the good fortune of  
and developed a new man  
manufacturing process he  
gas was being snuffed out*

—Ja

*the [1880s] gas industry that it found  
market for its product – space heat and  
light – even as the market for illuminating  
was being replaced by electric lighting.”*

*James Utterback, Mastering the Dynamics of Innovation (1994)*

## INTERACTIVE POLL



**Compared to 10 years ago, is the pace of change in your organization slower, about the same, or faster?**

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Fuels

## Generating Change

Change is Constant

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The generation fuel mix has evolved considerably since the 1950s

Change can be Fast or Slow

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New technologies have varied speeds of adoption or displacement

Change has Accelerated

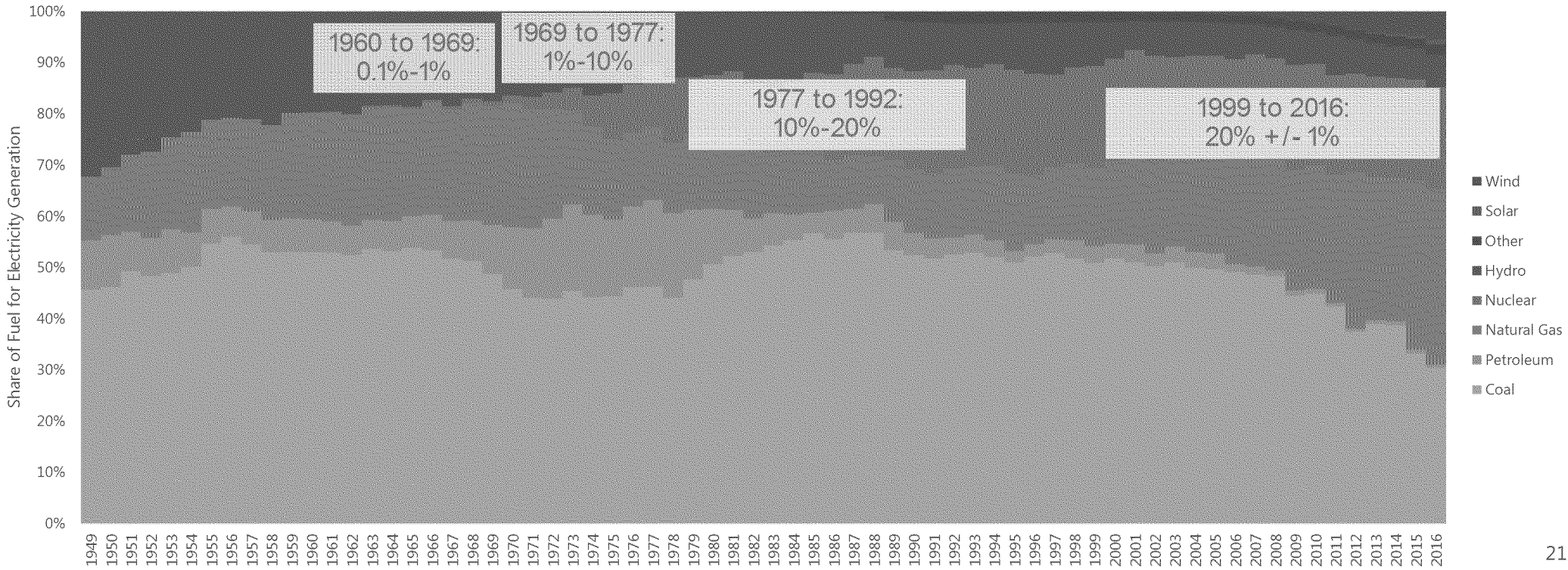
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A proposed metric for quantifying fuel mix changes

Constant  
Change

~~Nuclear: Rapid, Gradual, Steady~~

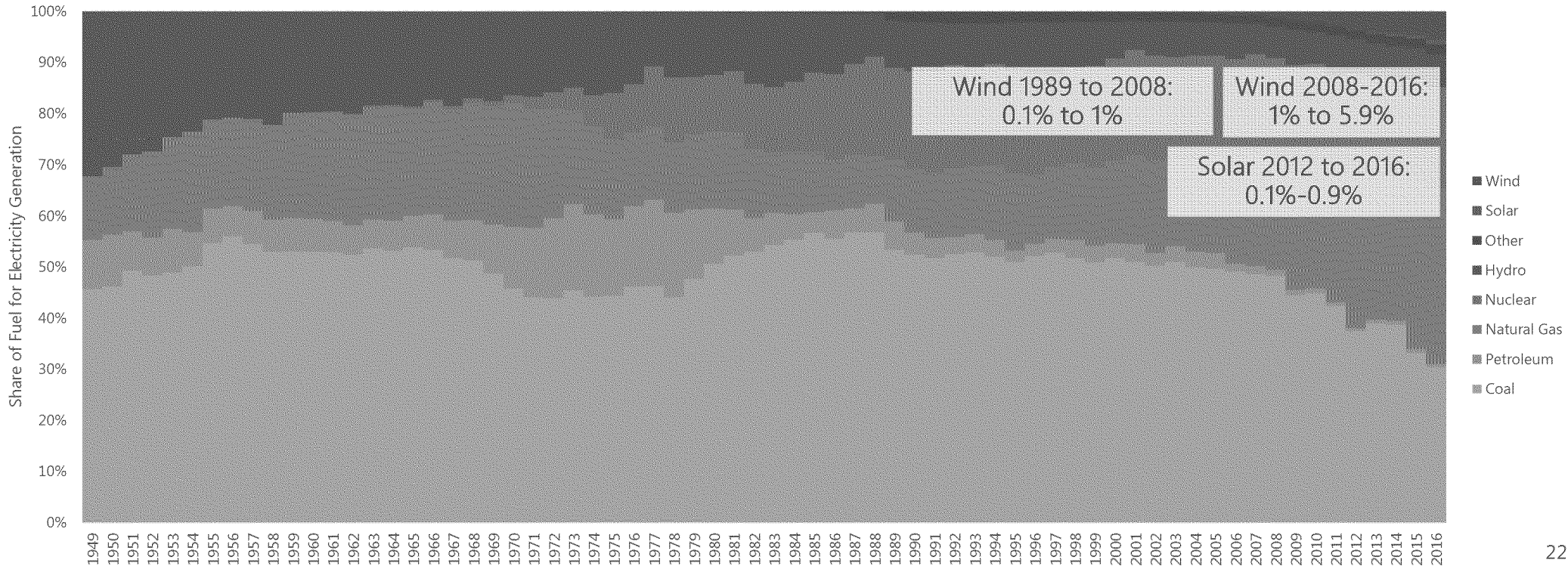
Share and Rate of Change in Electricity Generation Fuels



# Constant Change

## Renewables: Slow Growth, Fast Growth

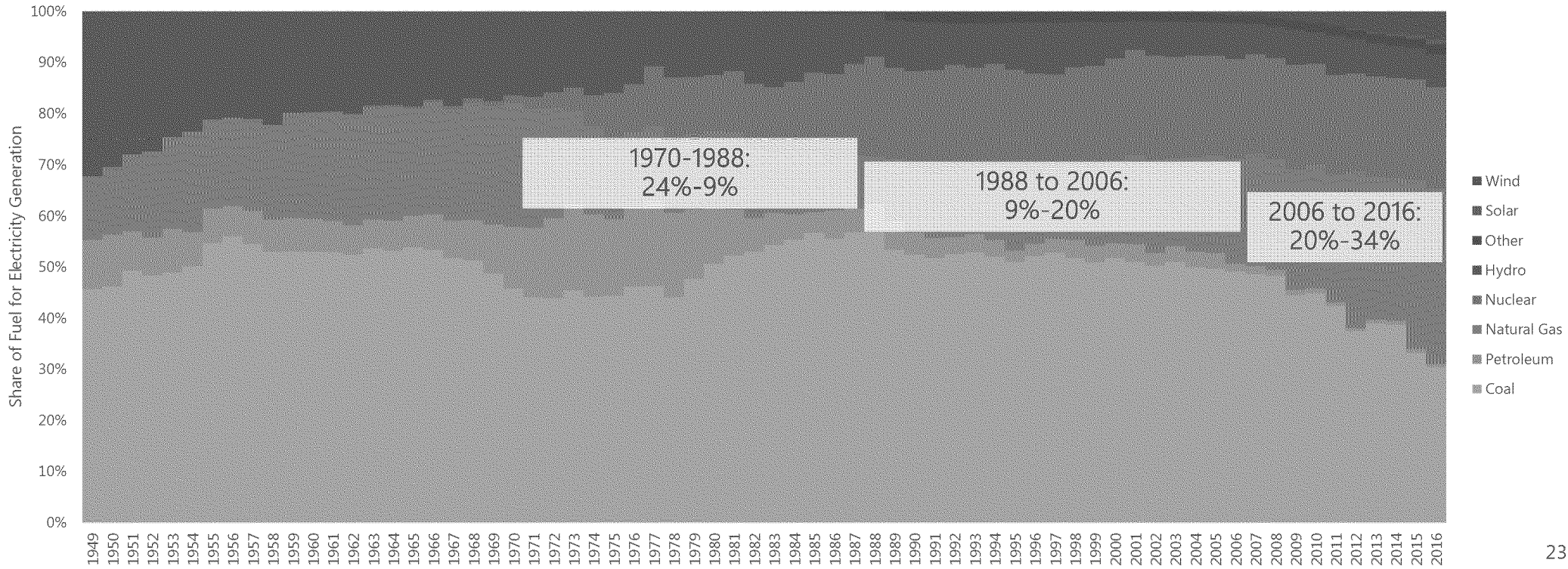
Share and Rate of Change in Electricity Generation Fuels



Constant  
Change

## Natural Gas: Decrease, Growth, Faster Growth

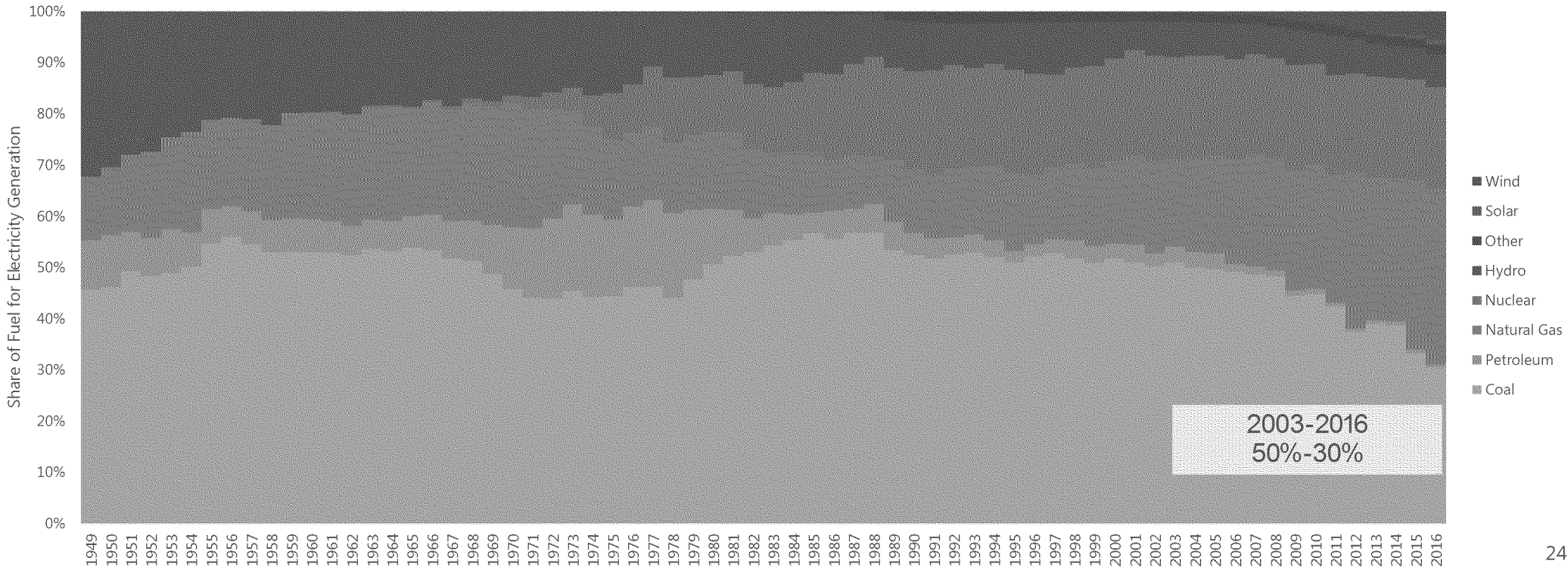
Share and Rate of Change in Electricity Generation Fuels



Constant  
Change

Coal: ~~Steady~~ Decrease

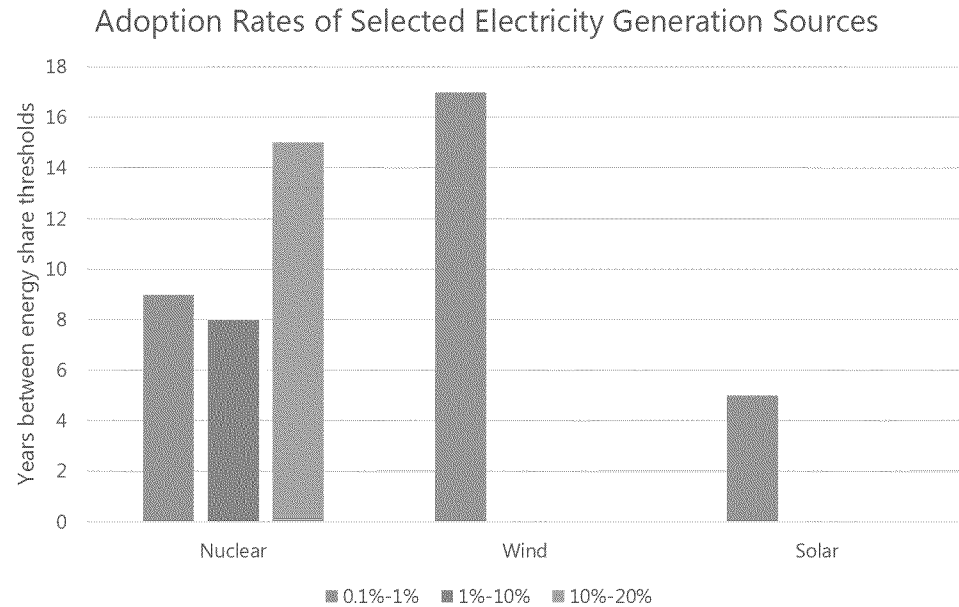
Share and Rate of Change in Electricity Generation Fuels



# Fast or Slow

## New technologies have varied in adoption speed

- Nuclear: 32 years to reach 20% energy share
- Wind: 25 years between first appearance on EIA data and 1% threshold
- Solar: nearly a decade of accelerating adoption rates

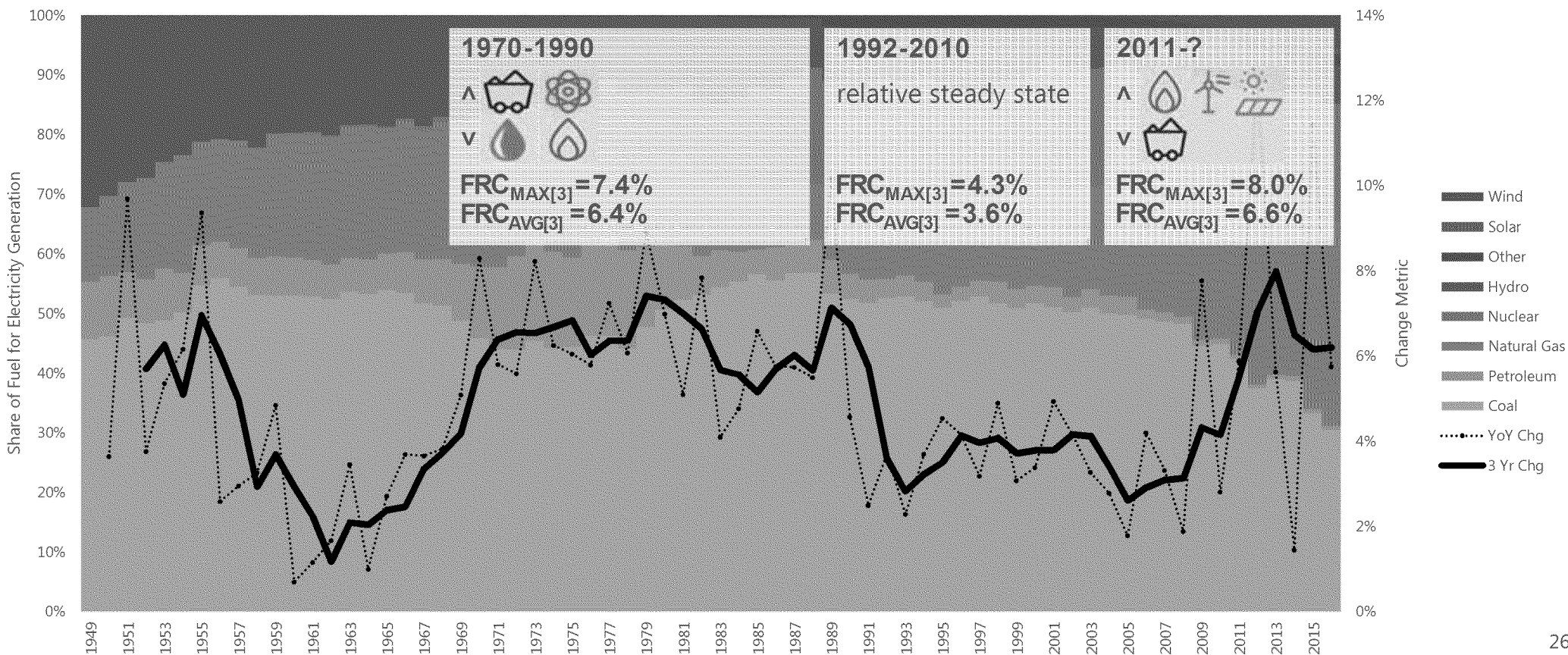


# Accelerating Change

## Fuel Rate of Change Metric: Highest Observed Index in 2013

$$= \text{SUM} [ (\text{fuels } f) \{ \text{abs}(\text{PCT} \quad ) \} ]$$

Share and Rate of Change in Electricity Generation Fuels



## Trends

### From the Staff Report on Electricity Markets and Reliability

"The low price of natural gas has resulted in the competitive displacement of coal in many of the Nation's markets."  
(p. 113)

"Since 2007, the contribution to total generation from wind and solar has grown quickly, accelerated by government policies and mandates."  
(p. 13)

"High penetration of VRE into the wholesale electricity markets could increase cycling of conventional power plants."  
(p. 154)

# All Energy

## Natural gas: a major primary energy source since the 1950s

U.S. Primary Energy Sources



## INTERACTIVE POLL



**How will the rate of change in generation fuels over the next 20 years compare to the last 20?**

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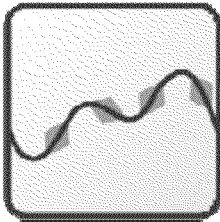


**DIVERGING PATHS**  
to the  
**FUTURE**

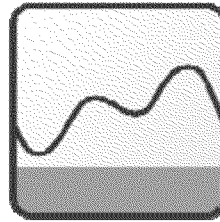
# Possibilities

## Potential ~~roads ahead~~ for natural gas

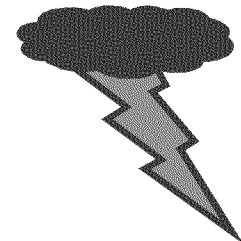
1. Ramp-focused future



2. Energy-Centric Dispatch



3. Reliability

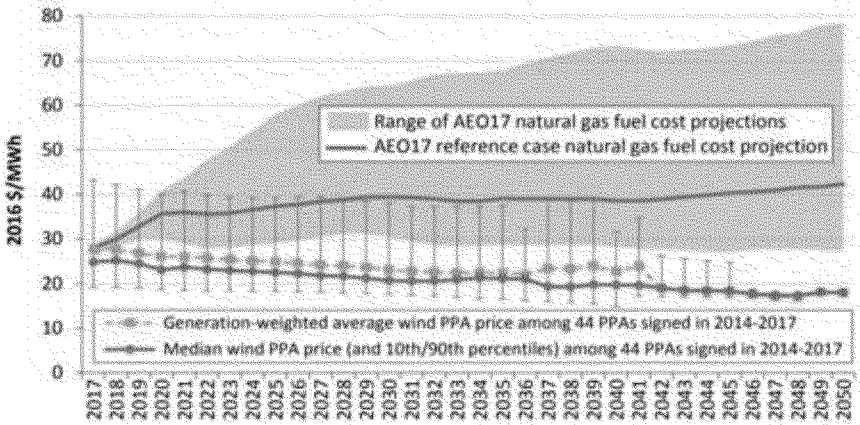


# 1

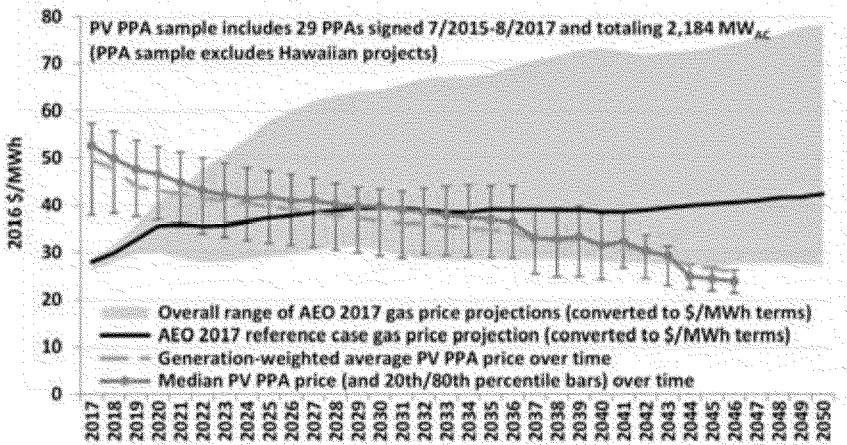
## Increased Ramp Dispatch with VERs

“...[U]tilities have increasingly begun replacing expensive fuel through self built renewable generation.” Dumoulin Smith

Source: Julien Dumoulin-Smith, “Turning on the lights: an electric utilities, power, and renewables overview,” Bank of America Merrill Lynch, October 23, 2017



Source: Ryan Wiser, Mark Bolinger, "2016 Wind Technologies Market Report: Summary," August 2017

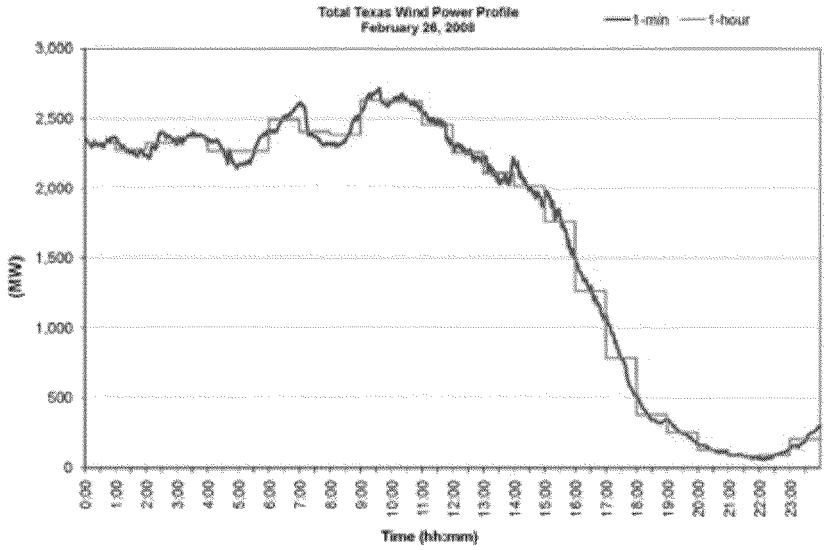


Source: Mark Bolinger, Joachim Seel, Kristina Hamachi LaCommare, "Utility-Scale Solar 2016," September 2017

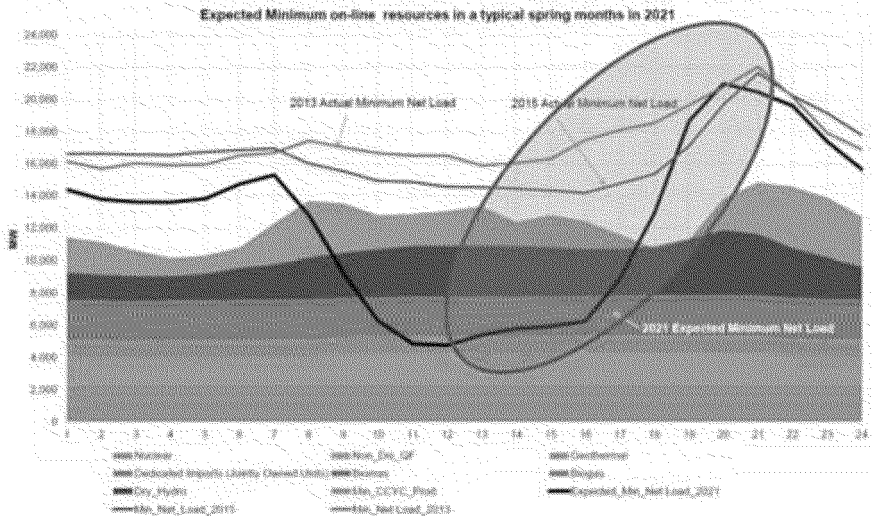
# 1

## Increased Ramp Dispatch with VERs

“The ISO has identified a growing need for downward flexible capacity to address over generation.” CAISO



Source: Yih-huei Wan, "Analysis of Wind Power Ramping Behavior in ERCOT," March 2011, NREL/TP-5500-49218

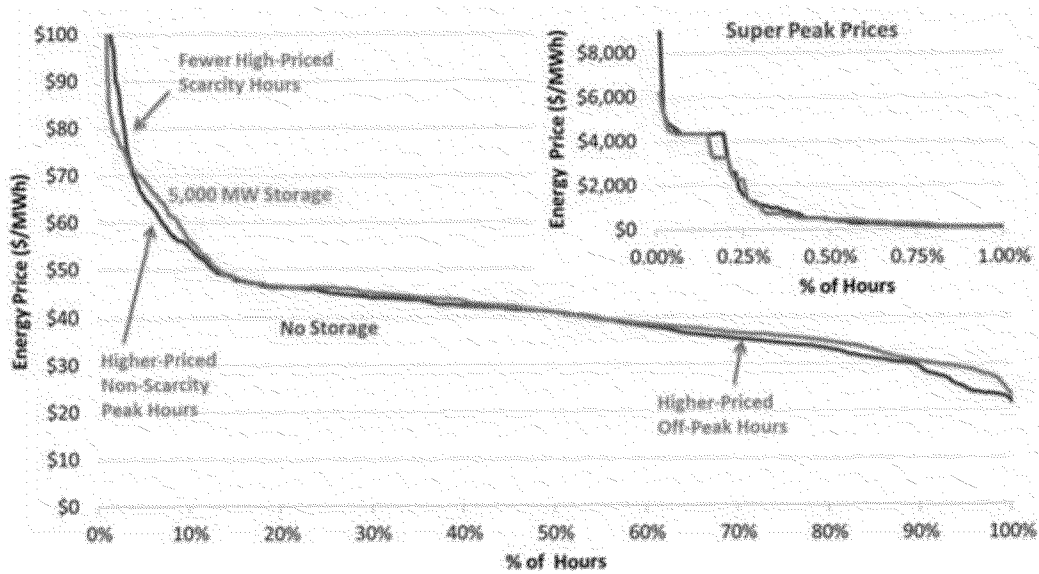


Source: CAISO, "Flexible Resource Adequacy Supplemental Issue Paper," Nov. 2015

# 2a

## Increased Energy Dispatch with Storage

"[P]lants recover their fixed costs...in somewhat more predictable fashion than on the system without storage." Brattle



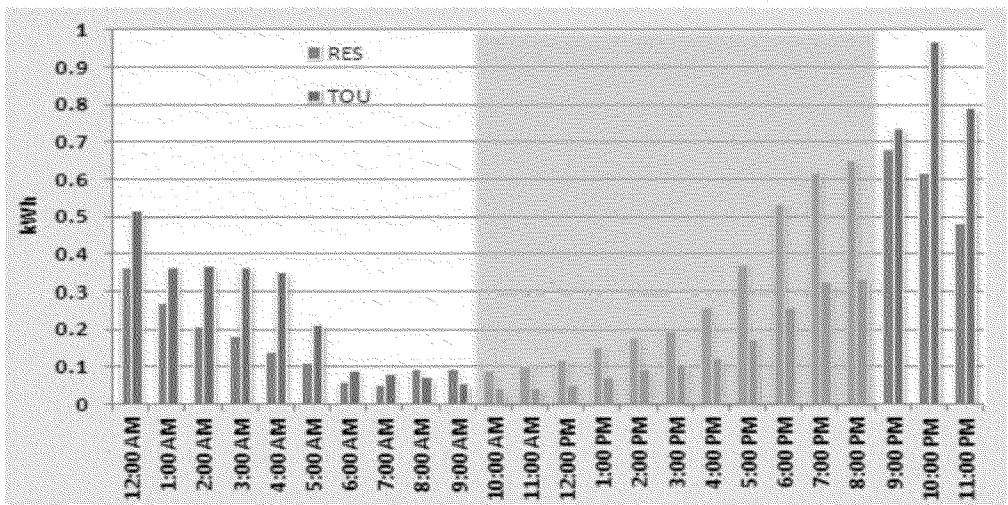
Source: Brattle, "The Value of Distributed Electricity Storage in Texas," March 2015

# 2b

## Increased Energy Dispatch with Electric Vehicles

“Customers took advantage of  
time based rates to save on  
overnight residential charging.”

DOE



**Figure 11. Charging Patterns with (TOU) and without (RES) Whole House Time-of-Use Rate during Summer Weekdays at Progress Energy (Peak period is in gray)**

Source: DOE, "Evaluating Electric Vehicle Charging Impacts and Customer Charging Behaviors," December 2014

# 3 Reliability

“If your power goes out, your generator comes on automatically.”

## BE PREPARED. NEVER LOSE POWER AGAIN.

Power Outages can strike any time, any place...

While hurricanes and tornadoes grab the headlines, the fact remains that nearly **60% of all weather-related power outages are caused by thunderstorms** that can occur almost anywhere. If you live outside severe-weather areas, you still are **very likely** to face as many—possibly even more—power outages due to **thunderstorms**.

### TOP CAUSES FOR POWER OUTAGES

Source: General Power Outage Explorer 2014

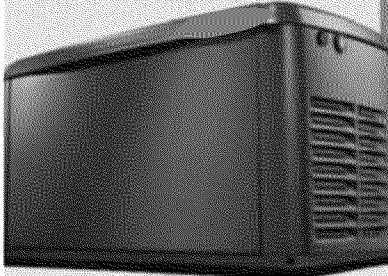
47% - STRONG STORMS
34% - SNOW / ICE STORMS
12% - EQUIPMENT FAILURES
7% - ALL OTHER UNKNOWN

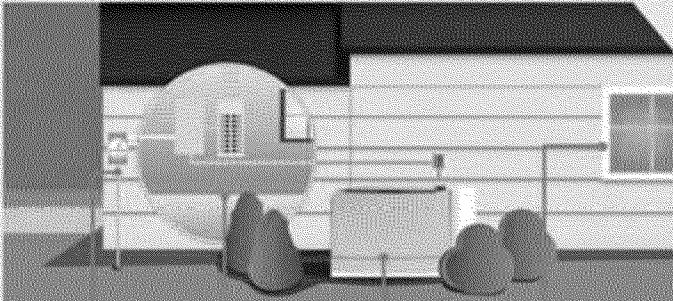
#### HOW IT WORKS

If your power goes out, your generator comes on – automatically. It's really that simple.

The generator system consists of a generator and transfer switch. The generator sits outside of your home just like a central air conditioner, while the transfer switch is located next to the main breaker box.

- Refrigeration/freezer for food and medicines
- **Furnace**
- Air conditioning
- Lighting – inside and outside
- Clean water for drinking and bathing
- **Sump pump**
- Kitchen appliances
- **Contact with the outside world:**  
Internet, cell phone chargers, TV, radio and more
- Sewer/ Well
- Washing and drying clothes
- **Security system**
- Garage door opener
- Fans
- **Medical equipment**
- Charging power tools for use during the emergency and post-outage cleanup
- **Necessary loss from temporary relocation:**  
hotel costs, dining out, property damage, etc.





- 1 Utility power is lost
- 2 Generator automatically detects a problem
- 3 Generator automatically turns on
- 4 Electricity is automatically restored

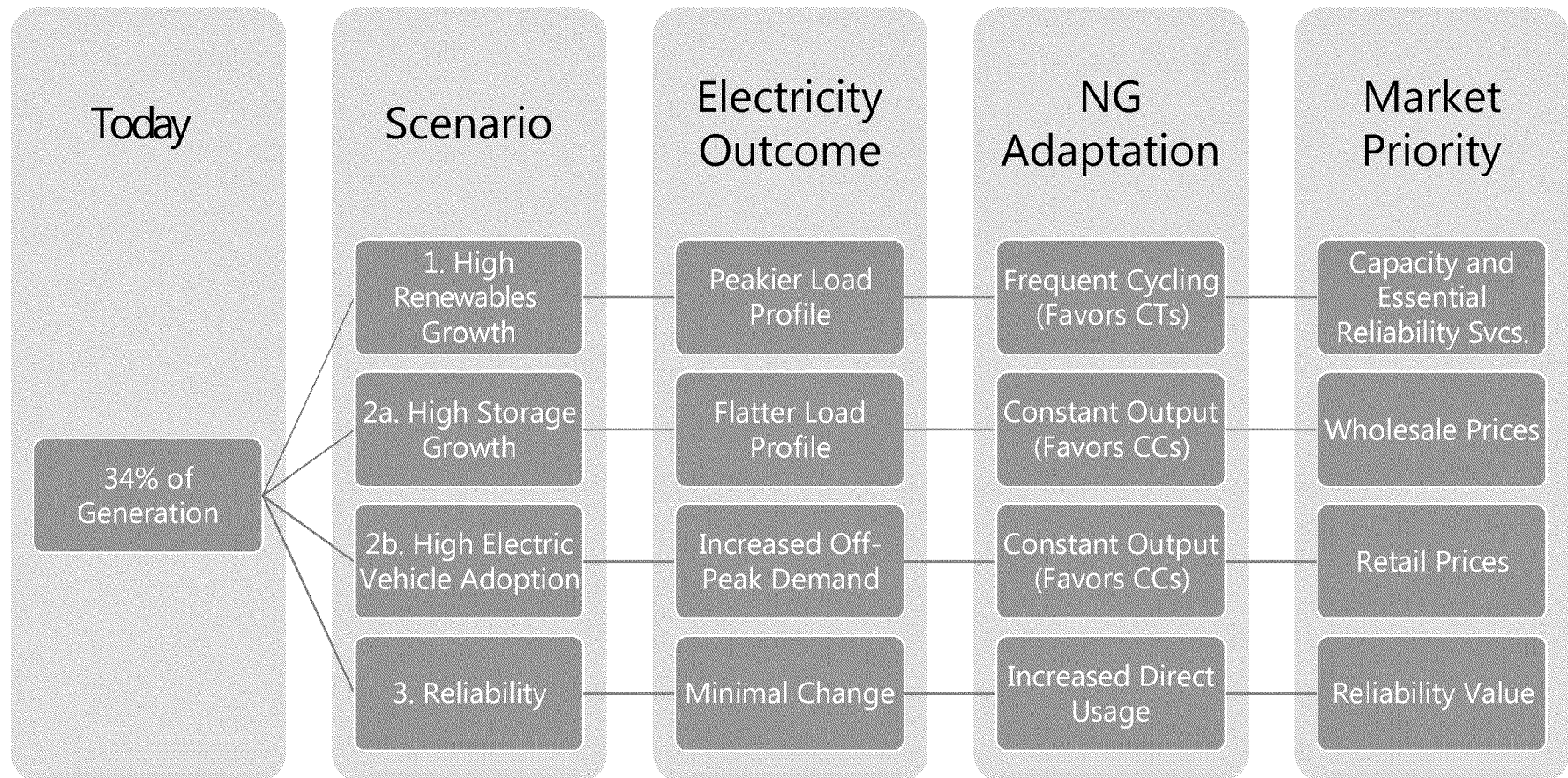
<b>72 MONTHS 0% FINANCING</b> <b>\$160/MONTH</b> <small>BACK UP 25% OF HOME</small>	<b>72 MONTHS 0% FINANCING</b> <b>\$185/MONTH</b> <small>BACK UP 50% OF HOME</small>	<b>72 MONTHS 0% FINANCING</b> <b>\$218/MONTH</b> <small>BACK UP 100% OF HOME</small>
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Price includes Generator, Installation of Gaslines, Installation of Electric lines, Mechanical permit, Electric permit, Gas Permit, County/City Inspections, Fee Needed for Work, Electric Sub Panel with Transfer Switch, Composite Slab, Gas Pressure Test, Grounding, Charged Battery, Help Secure HOA approval if needed and Final Start-up. **your one Stop Shop.**  
No Hidden Fees. Approval for Financing not Guaranteed. Some Homes will not Qualify for Generator or Promotion.

Source: Washington Post Express, Advertisement, September 15, 2017

# Decisions

## Scenarios for potential future roles of natural gas



# Financial Flows

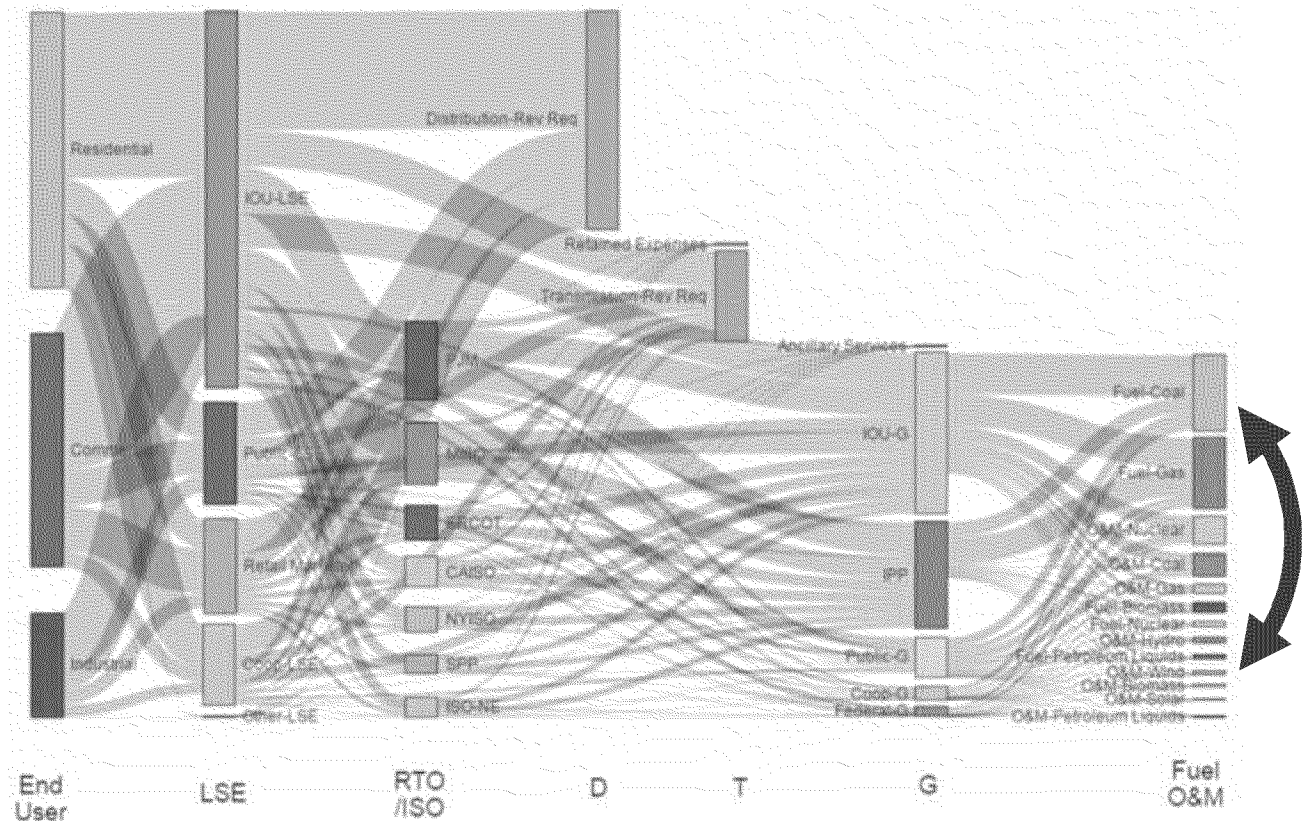
## Scenarios that involve competition among generation fuels

1. High Renewables Growth

2a. High Storage Growth

3. Reliability

Revenue Flows through the U.S. Power Sector  
(EPISA/ORNL Energy Finance Data Warehouse)



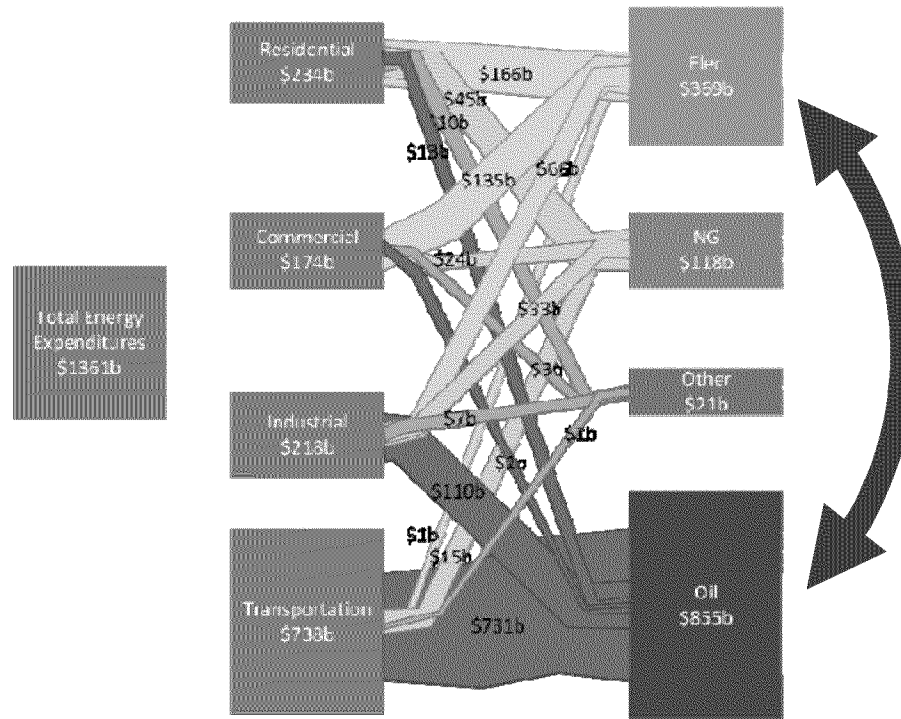
Zeng, Hendrickson, Lee, Chinthavali, Lin, Hsieh, Shankar. (2017). Energy finance data warehouse: Tracking revenues through the power sector. The Electricity Journal. 30. 4-9. 10.1016/j.tej.2017.03.001.

# Financial Flows

## Scenarios that involve growth of overall electricity demand

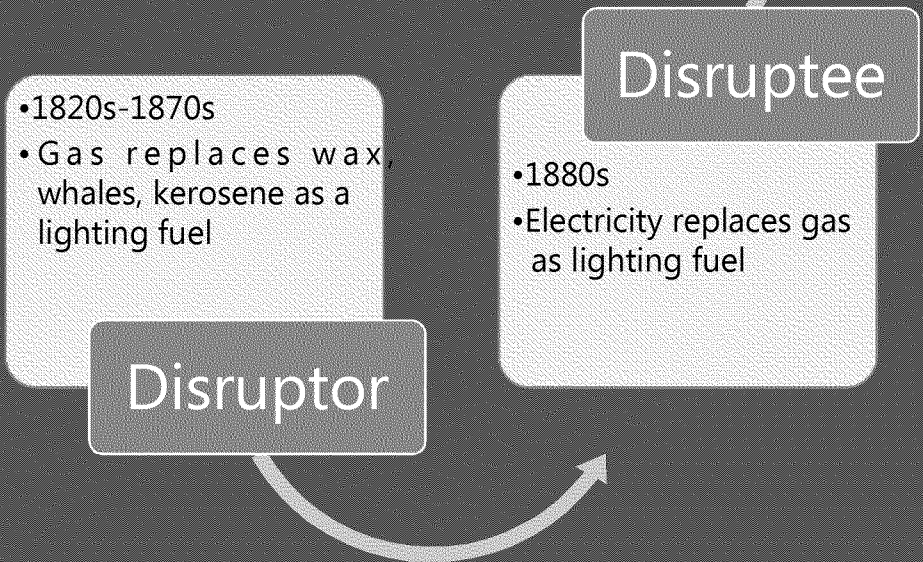
Revenue Flows through the U.S. Energy Sector  
(Prototype for EPSA/ORNL Energy Finance Data Warehouse)

2b. High Electric Vehicle Adoption



Zeng, Hendrickson, Lee, Chinthavali, Lin, Hsieh, Shankar. (2017). Energy finance data warehouse: Tracking revenues through the power sector. The Electricity Journal. 30. 4-9. 10.1016/j.tej.2017.03.001.

# CLOSING

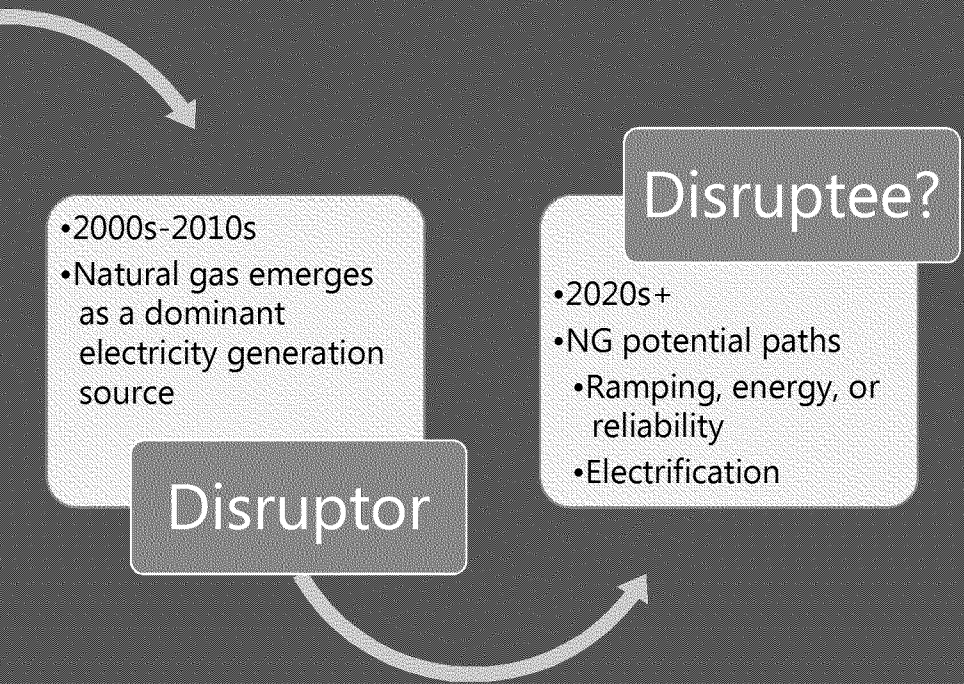


## Is change accelerating?

Yes, according to the *Fuel Rate of Change* metric.

## Is natural gas a disruptor or disruptee?

Yes.



**Eric Hsieh**

THANK YOU