U.S. Department of Energy
Analysis on Electricity Infrastructure

Carol Battershell, C3E Ambassador and
Principal Deputy Director, Office of Energy Policy and Systems Analysis
2017 C3E Symposium
DOE policy analysis team maintains analytic capabilities to assist DOE leadership throughout the policy design process

Policy analysis process

**Context**
- Evidence gathering
- Problem definition

**Options**
- Gap identification
- Identification of alternatives

**Evaluation**
- Selection of evaluation criteria
- Modeling outcomes
- Evaluating tradeoffs

The Department of Energy policy team distills **clarity from complexity** using a portfolio of tools and expertise...
Data
Secretary Perry requested a study of grid resilience and reliability in April 2017

The memo asked staff to examine:

- The evolution of wholesale electricity markets
- Compensation for resilience in wholesale energy and capacity markets
- Premature baseload power plant retirements
Dramatic changes in electricity system

Traditional One-Way Flow
Electricity Supply Chain

Emerging 21st Century
Electricity Two-Way Flow
Supply Chain

Source: QER Second Installment
### Different types of utilities and load-serving entities are in different parts part of the chain

<table>
<thead>
<tr>
<th>Source: QER 1.2 Table A-5</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Generation</th>
<th>Transmission</th>
<th>Distribution</th>
<th>Retail</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Diagram" /></td>
<td><img src="image2.png" alt="Diagram" /></td>
<td><img src="image3.png" alt="Diagram" /></td>
<td><img src="image4.png" alt="Diagram" /></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>State-Regulated IOU</strong></th>
<th><strong>Rural Electric Cooperative</strong></th>
<th><strong>Publicly Owned</strong></th>
<th><strong>Federally Owned</strong></th>
<th><strong>Merchant</strong></th>
<th><strong>Competitive Retail Energy Supplier</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Oklahoma Gas &amp; Electric</td>
<td>–</td>
<td>Los Angeles Department of Water &amp; Power</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Pepco</td>
<td>Southern Maryland Electric Cooperative</td>
<td>Clallam County Public Utility District</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>DTE Energy; Consumers Energy</td>
<td>Basin Electric G&amp;T</td>
<td>New York Power Authority</td>
<td>Tennessee Valley Authority</td>
<td>LS Power</td>
<td>–</td>
</tr>
<tr>
<td>Mt. Carmel Public Utility Co.</td>
<td>Kenergy</td>
<td>Nashville Electric Service</td>
<td>Western Area and Southwestern Power Administrations</td>
<td>ITC; Hudson Transmission; Transource Energy; Clean Lines Energy Partners</td>
<td>–</td>
</tr>
<tr>
<td>–</td>
<td>Upper Missouri Power Cooperative</td>
<td>Transmission Agency of Northern California</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>–</td>
<td>–</td>
<td>Wyoming Municipal Power Agency</td>
<td>Bureau of Reclamation</td>
<td>Calpine; BP Energy; Tenaska</td>
<td>–</td>
</tr>
<tr>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>Direct Energy; Veteran Energy</td>
</tr>
</tbody>
</table>

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Office of Energy Policy and Systems Analysis
Distribution utilities are diverse with unique opportunities and challenges

<table>
<thead>
<tr>
<th></th>
<th>Investor-Owned</th>
<th>Municipal</th>
<th>Cooperative</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of organizations</td>
<td>200</td>
<td>2,000</td>
<td>912</td>
<td>3,112</td>
</tr>
<tr>
<td>Fraction of distribution line miles</td>
<td>50%</td>
<td>7%</td>
<td>43%</td>
<td></td>
</tr>
<tr>
<td>Total customers</td>
<td>104 million</td>
<td>21 million</td>
<td>18.5 million</td>
<td>144 million</td>
</tr>
<tr>
<td>Customers per line mile (density)</td>
<td>34 - Medium</td>
<td>48 - High</td>
<td>7.4 - Low</td>
<td></td>
</tr>
<tr>
<td>Percentage of Sales by Customer Type</td>
<td>industrial 24%</td>
<td>residential 37%</td>
<td>commercial 39%</td>
<td></td>
</tr>
<tr>
<td>Total Sales (billion kWh)</td>
<td>2,708 73%</td>
<td>570 16%</td>
<td>413 11%</td>
<td>3,691</td>
</tr>
<tr>
<td>Revenue ($ per mile of line)</td>
<td>$75,500 / mile</td>
<td>$113,000 / mile</td>
<td>$15,000 / mile</td>
<td></td>
</tr>
<tr>
<td>Total Revenues ($ billion)</td>
<td>$273 billion</td>
<td>$53 billion</td>
<td>$40 billion</td>
<td></td>
</tr>
</tbody>
</table>
Trends
- 2002-2006: restructuring. Majority of retirements are smaller, older merchant plants
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2007-2010: economic recession, shale gas, Mass v. EPA, strong utility-scale wind growth
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• 2007-2010: economic recession, shale gas, Mass v. EPA, strong utility-scale wind growth
• 2011-2015: sustained low electricity demand and NG prices, MATS deadline, CPP finalized
• 2002-2006: restructuring. Majority of retirements are smaller, older merchant plants
• 2011-2015: sustained low electricity demand and NG prices, MATS deadline, CPP finalized
• 2016 onward: where do we go from here?
Between 2002-2016, 4.6 GW or ~5% of the total nuclear fleet announced retirement.

BNEF estimates that 34 of the total 60 plants are operating in the red.

Many plants closing well before their operating licenses expire.
Drivers
Retirements: Key drivers

1. Advantaged economics of natural gas-fired generation
   - Shale gas development has significantly expanded the availability of natural gas and lowered its cost

2. Low growth in electricity demand
   - Electricity demand historically had risen with economic growth (real GDP), but the two began decoupling around 2000

3. Environmental regulations
   - A suite of regulations affecting the electricity generation sector had implementation deadlines between 2011 and 2021, stemming from statutes enacted between 1970 and 1990

4. Dispatch of VRE has negatively impacted baseload plant economics
   - Total VRE generation consistently reaches new record levels
Retirements: Natural gas supply

Conventional and Shale Natural Gas Production, 2007–2016

Shale gas development has significantly expanded availability and lowered costs

And natural gas plants have had increasingly more favorable heat rates than coal and nuclear
Retirements: Demand and economic growth decoupling

Demand growth has stalled since 2005, despite economic recovery after the recession.

Changing policy and market conditions have made it challenging to accurately forecast electricity demand.
Retirements: Environmental regulations

- Reported planned retirements suggest that approximately 27,000 MW or 8.5 percent of 2011 coal-fired capacity was rendered uneconomic under the combination of regulatory compliance costs, low demand growth, and low natural gas prices.
- Difficult to tease out relative impact of regulations on retirements in isolation.
Retirements: VRE penetration

VRE penetration is steadily rising...

... but according to LBNL research, existing data do not suggest a correlation between VRE penetration and thermal plant retirements.
Findings
Key findings

Power Plant Retirements

• A combination of market and policy forces has accelerated the closure of a significant number of traditional baseload power plants:
  • Low natural gas prices
  • Low electricity demand growth
  • Environmental regulations
  • Increased VRE penetration

Reliability and Resilience

• Bulk power system reliability is adequate today despite significant VRE growth, but long-term concerns about baseload retirements merit further study
  • Markets recognize and compensate reliability, but more work is needed to better understand resilience across a variety of grid and market scenarios
  • Growing interdependence on natural gas
Key findings

Wholesale Markets and Affordability

• Changing circumstances are challenging electricity markets
  • Negative pricing in certain areas
  • Markets do not currently value all attributes of electricity provision
    • The “missing money” problem
    • Examples: jobs, local economic development, national security
As the electric system evolves, more objectives add complexity to investment and policy decisions

“Demands on electricity markets also are evolving... to recognize value associated with generation plants beyond their cost effectiveness and reliability attributes.” -- PJM
Recommendations
Key policy recommendations

Department of Energy
- Support industry efforts and focus R&D to enhance system resilience
- Accelerate and reduce costs for re/licensing and permitting
- Facilitate programs for workforce development
- Increase coordination of electric and natural gas industries

Federal Energy Regulatory Commission (FERC)
- Expedite efforts to reform energy price formation
- Value new/existing essential reliability services

Environmental Protection Agency (EPA)
- Allow coal-fired power plants to improve efficiency and reliability without triggering new regulatory approvals and associated costs

Nuclear Regulatory Commission (NRC)
- Revisit nuclear safety rules
- Ensure safety without unnecessarily adding costs
Implementation and Lessons Learned
## Hurricanes Since 2000 Causing More than $1 Billion in Total Economic Damage

<table>
<thead>
<tr>
<th>DATE</th>
<th>HURRICANE</th>
<th>TOTAL DAMAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>OCT.'02</td>
<td>Lili</td>
<td>$1.3 billion total</td>
</tr>
<tr>
<td>SEPT.'03</td>
<td>Isabel</td>
<td>$7.7B</td>
</tr>
<tr>
<td>AUG.'04</td>
<td>Charley</td>
<td>$20.9B</td>
</tr>
<tr>
<td>SEPT.'04</td>
<td>Frances</td>
<td>$12.3B</td>
</tr>
<tr>
<td>SEPT.'04</td>
<td>Ivan</td>
<td>$25.8B</td>
</tr>
<tr>
<td>SEPT.'04</td>
<td>Jeanne</td>
<td>$9.8B</td>
</tr>
<tr>
<td>JULY '05</td>
<td>Dennis</td>
<td>$3.5B</td>
</tr>
<tr>
<td>AUG.'05</td>
<td>Katrina</td>
<td>$147.4B</td>
</tr>
<tr>
<td>SEPT.'05</td>
<td>Rita</td>
<td>$22.4B</td>
</tr>
<tr>
<td>OCT.'05</td>
<td>Wilma</td>
<td>$22.4B</td>
</tr>
<tr>
<td>JULY '08</td>
<td>Dolly</td>
<td>$1.1B</td>
</tr>
<tr>
<td>SEPT.'08</td>
<td>Gustav</td>
<td>$6.7B</td>
</tr>
<tr>
<td>SEPT.'08</td>
<td>Ike</td>
<td>$33.7B</td>
</tr>
<tr>
<td>AUG.'11</td>
<td>Irene</td>
<td>$15.5B</td>
</tr>
<tr>
<td>AUG.'12</td>
<td>Isaac</td>
<td>$3.2B</td>
</tr>
<tr>
<td>OCT.'12</td>
<td>Sandy</td>
<td>$69.9B</td>
</tr>
<tr>
<td>OCT.'16</td>
<td>Matthew</td>
<td>$10.0B</td>
</tr>
<tr>
<td>AUG.'17</td>
<td>Harvey</td>
<td>$95B (Moody Analytics estimate)</td>
</tr>
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**Share covered by federal spending**

On average, federal spending has covered 62 percent of total hurricane damage since 2000.

### Discretionary federal hurricane spending, 2000-15

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>FEMA disaster relief fund</td>
<td>44%</td>
</tr>
<tr>
<td>HUD grants</td>
<td>20%</td>
</tr>
<tr>
<td>Army Corps</td>
<td>11%</td>
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<tr>
<td>Other spending</td>
<td>26%</td>
</tr>
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**Congress authorized $7.4 billion for the federal disaster relief fund and $450 million for Small Business Administration disaster loans. Total federal spending will rise as additional funds are spent via HUD block grants, Army Corps of Engineers projects, FEMA flood insurance and other programs. Some of these funds may also be used to respond to damage from Hurricane Irma.**

**SOURCE:** Politico Pro DataPoint
Post-Katrina Lessons Learned: Entergy Resilience Planning & Investment Work

Restoration time has improved since Rita and Katrina resilience rebuilding¹

- Restoration time for 90% of customers was 5 days for Isaac vs 17 days for Katrina
- Efforts shifted from replacing transmission structures to that of replacing insulators on towers

Isaac (Cat. 1/2012); Ike (Cat. 2/2008); Gustav (Cat. 2/2002); Rita (Cat. 3/2005); Katrina (Cat. 3/2005)

¹ Based on non-coincident system peak
² Excludes extended restoration customers; Rita 800K start is net of continued Katrina restorations in progress
³ Excludes 1,649 customers projected to be unable to receive service (as of September 6)

Improved building codes; targeted hardening of transmission and distribution lines, and refineries; elevating/relocating assets, backup generation, vegetation management

¹COMMENTS ON THE QUADRENNIAL ENERGY REVIEW APRIL 11, 2014 PUBLIC MEETING “ENHANCING INFRASTRUCTURE RESILIENCY AND ADDRESSING VULNERABILITIES,” HELD IN WASHINGTON, DC
$1.22 Billion Resilience Program:

- **Electric System**
  - $620 million to raise, relocate or protect 29 switching and substations that were damaged by water in recent storms.
  - $100 million to create redundancy in the system, reducing outages when damage occurs.
  - $100 million to deploy smart grid technologies to better monitor system operations to increase our ability to more swiftly deploy repair teams.

- **Gas System**
  - $350 million to replace and modernize 250 miles of low-pressure cast iron gas mains in or near flood areas.
  - $50 million to protect five natural gas metering stations and a liquefied natural gas station affected by Sandy or located in flood zones.

**Making New Jersey Energy Strong:** Reliability and Resiliency in New Jersey.


Post-Sandy Lessons Learned: New Jersey Public Service Electric and Gas
Puerto Rico: Before & After