# PJM's Evolving Resource Mix and System Reliability


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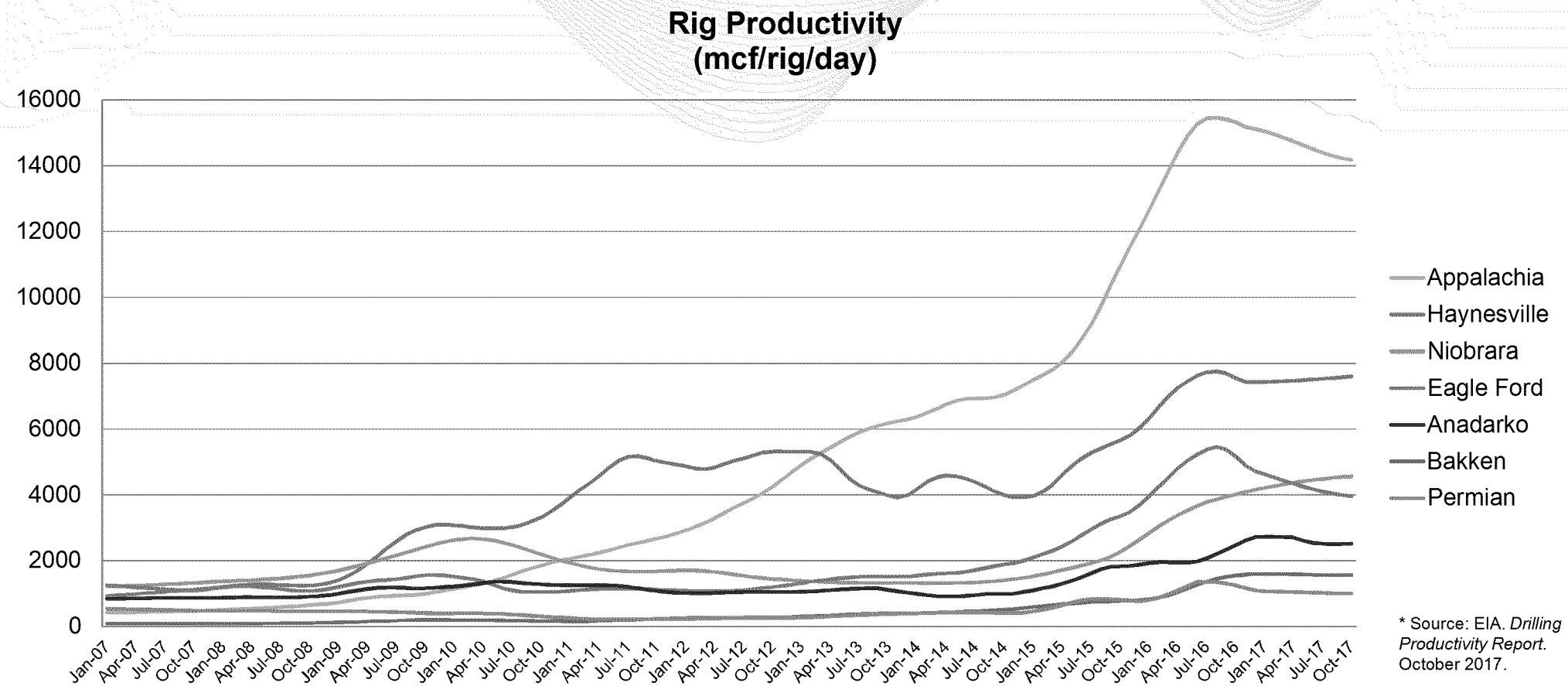
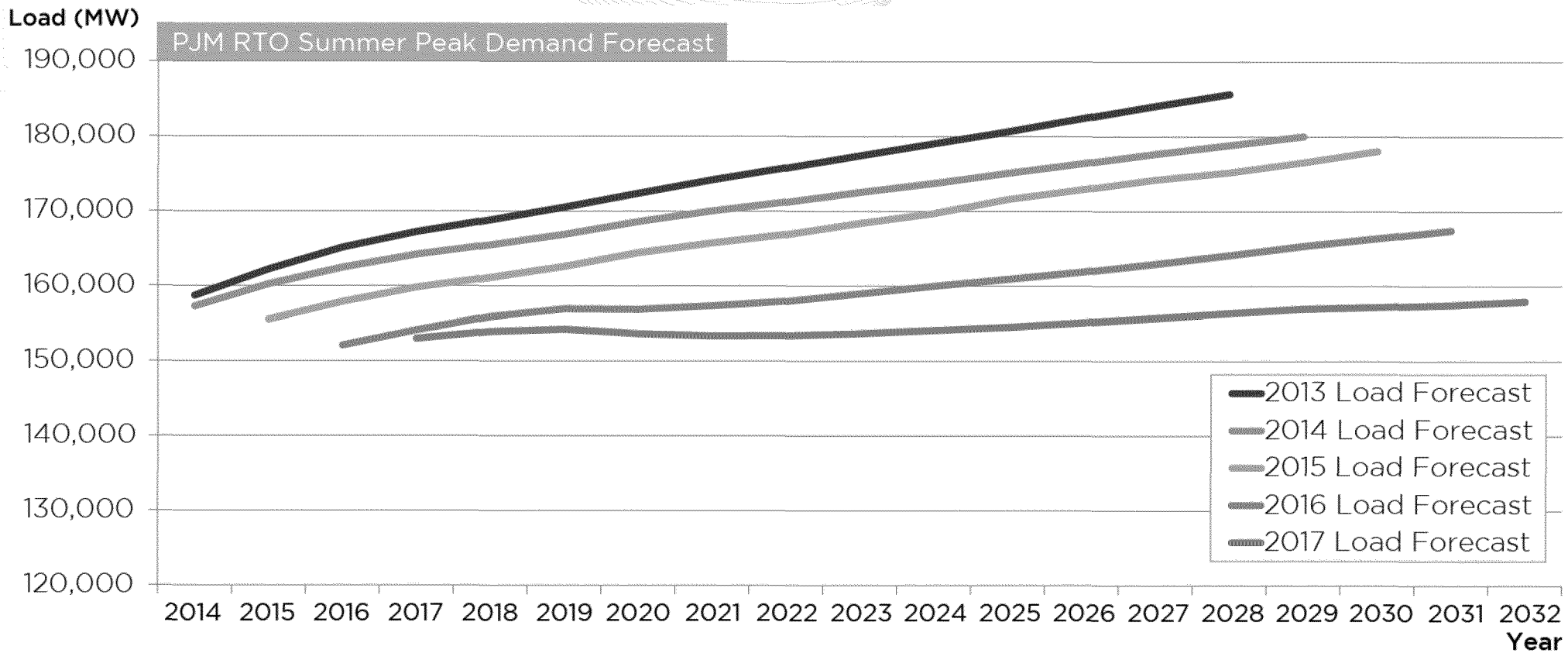
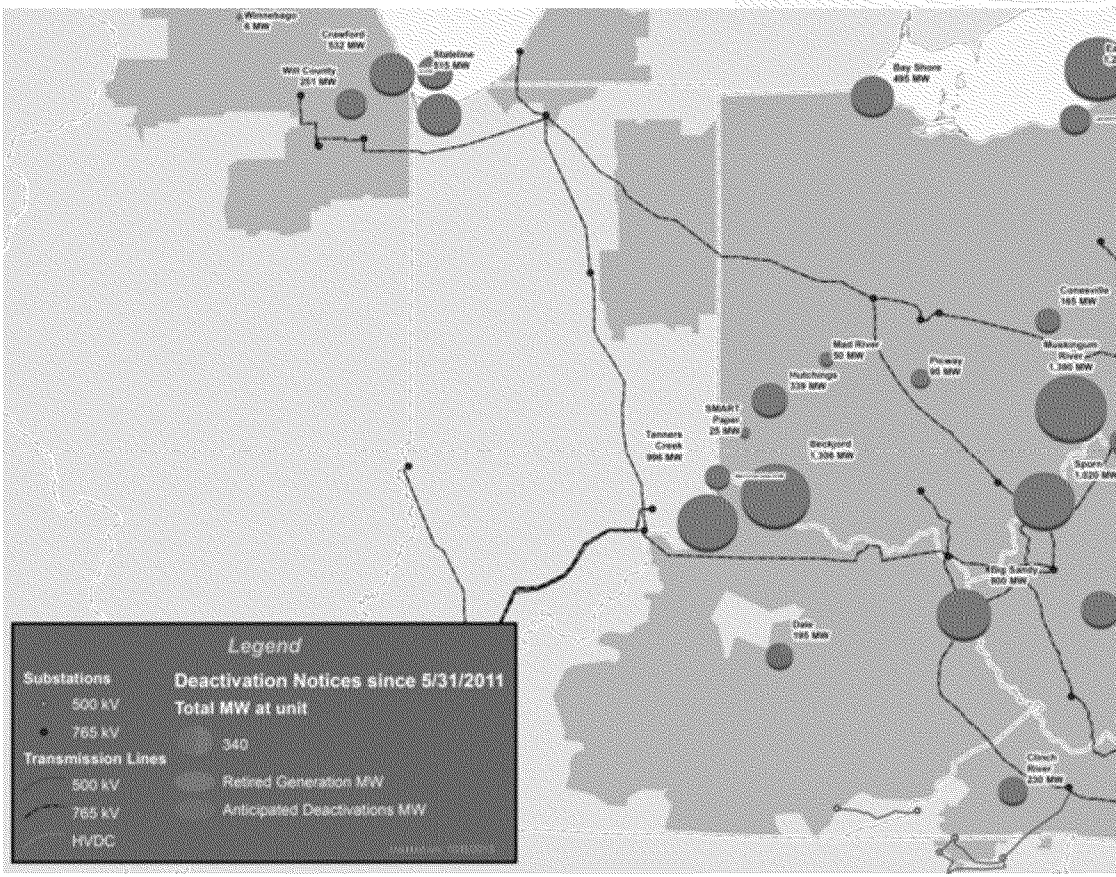
# Main Driver: Natural Gas



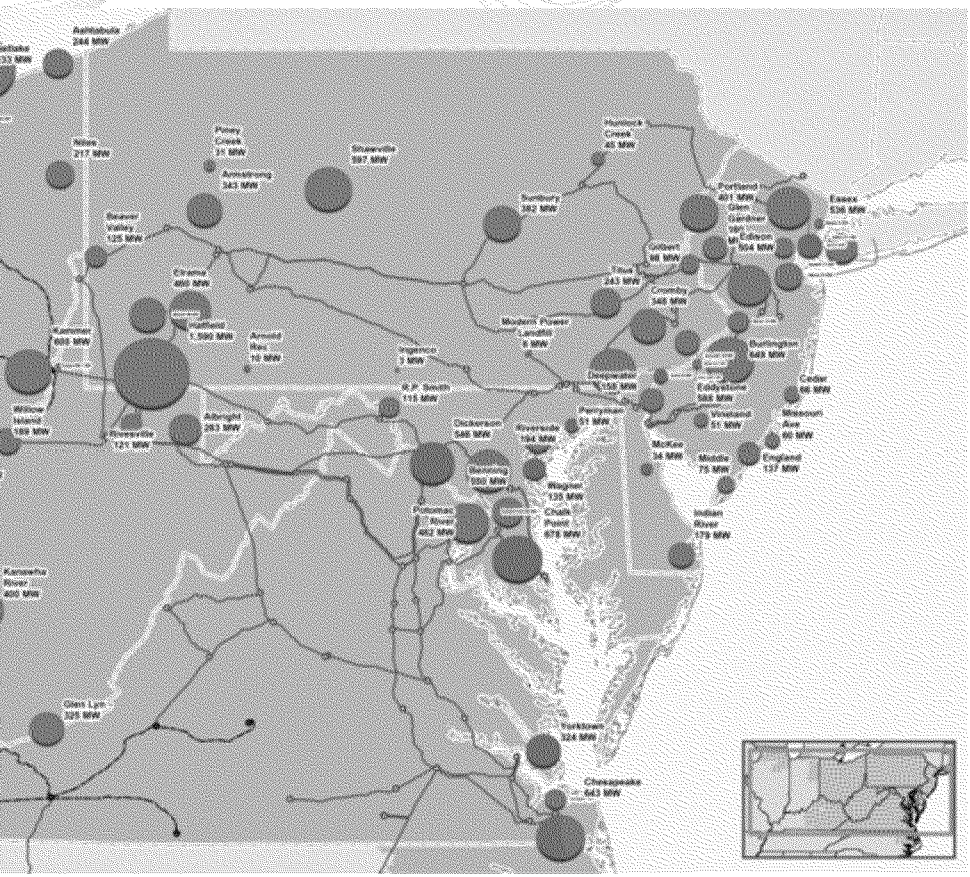

* Source: EIA. *Drilling Productivity Report*. October 2017.

# Declining Electricity Demand Growth

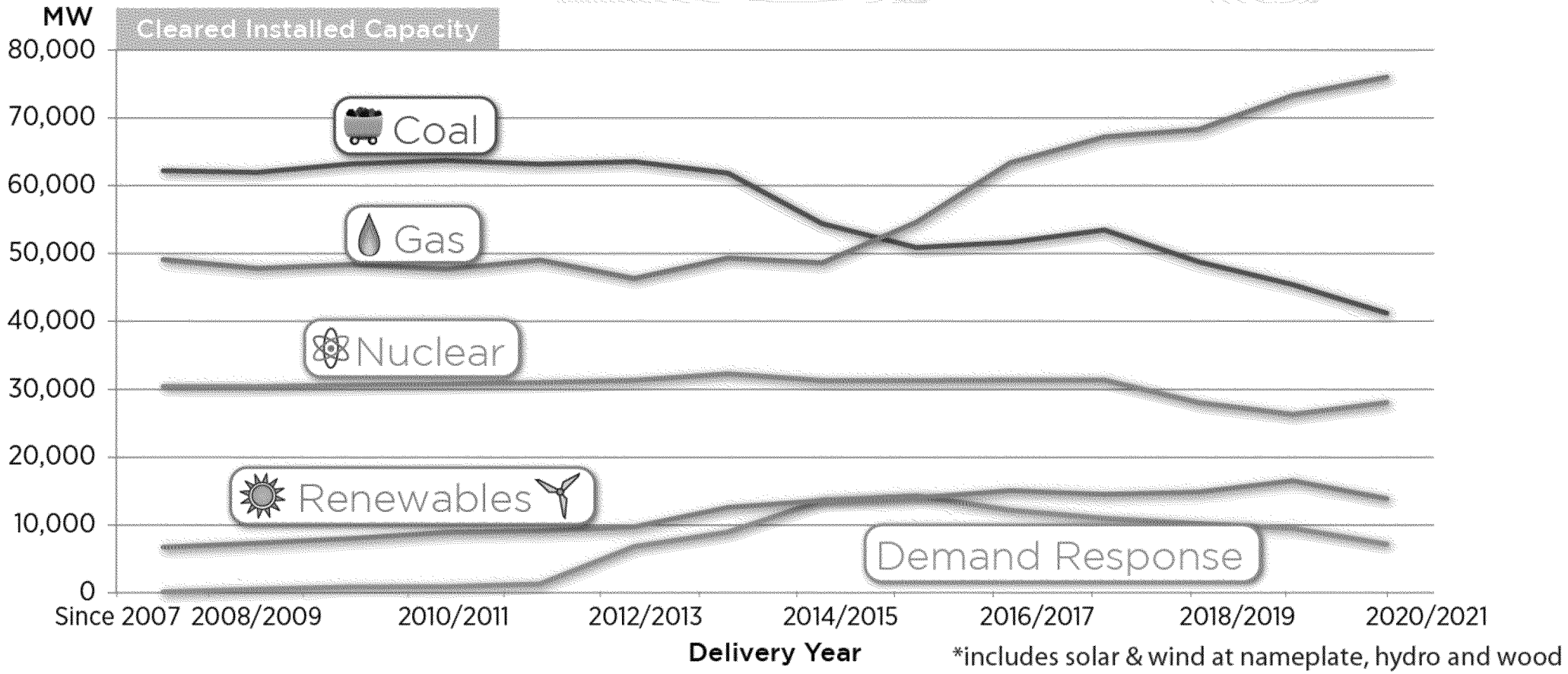



Winnebago
6 MW
Crawford
532 MW
Will County
251 MW
Stateline
515 MW
Bay Shore
495 MW
Conesville
165 MW
Muskingum River
1,386 MW
Mad River
50 MW
Hutchings
339 MW
Picway
95 MW
SMART Paper
25 MW
Tanners Creek
996 MW
Beckjord
1,306 MW
Big Sandy
800 MW
Dale
195 MW
Clinch River
230 MW
Legend
Substations
500 kV
765 kV
Transmission Lines
500 kV
765 kV
HVDC
Deactivation Notices since 5/31/2011
Total MW at unit
340
Retired Generation MW
Anticipated Deactivations MW

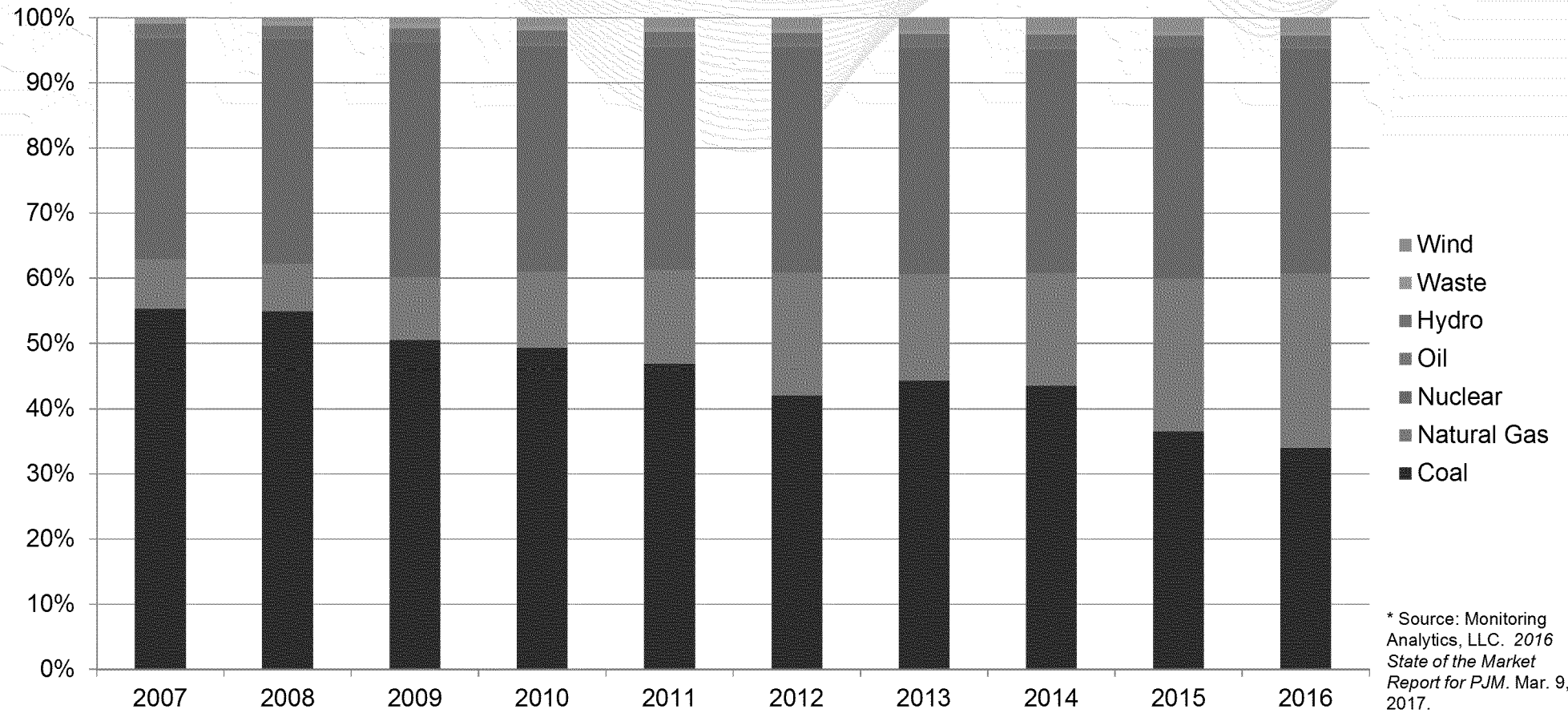
# Generation Retirements



# Capacity Market Results



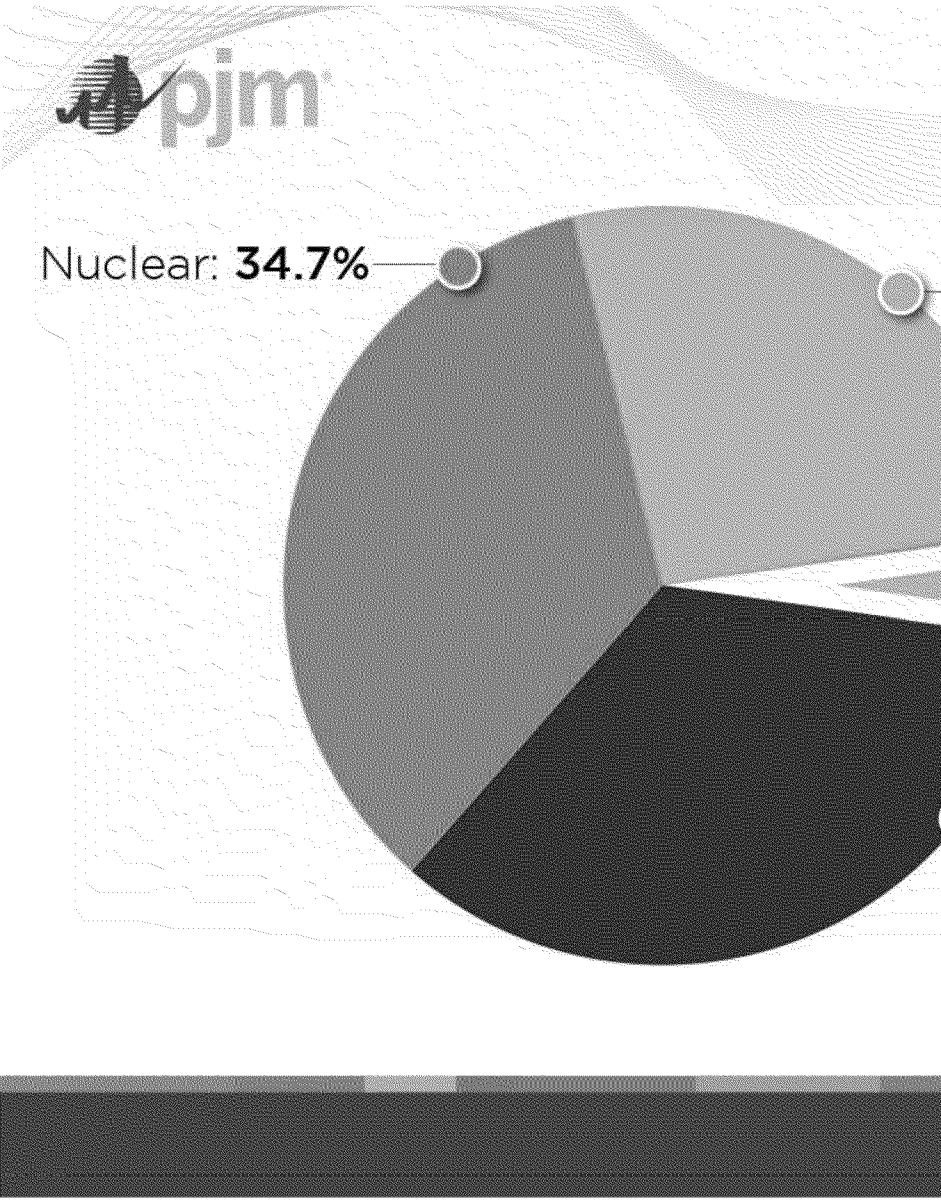
# Changing Energy Market Trends



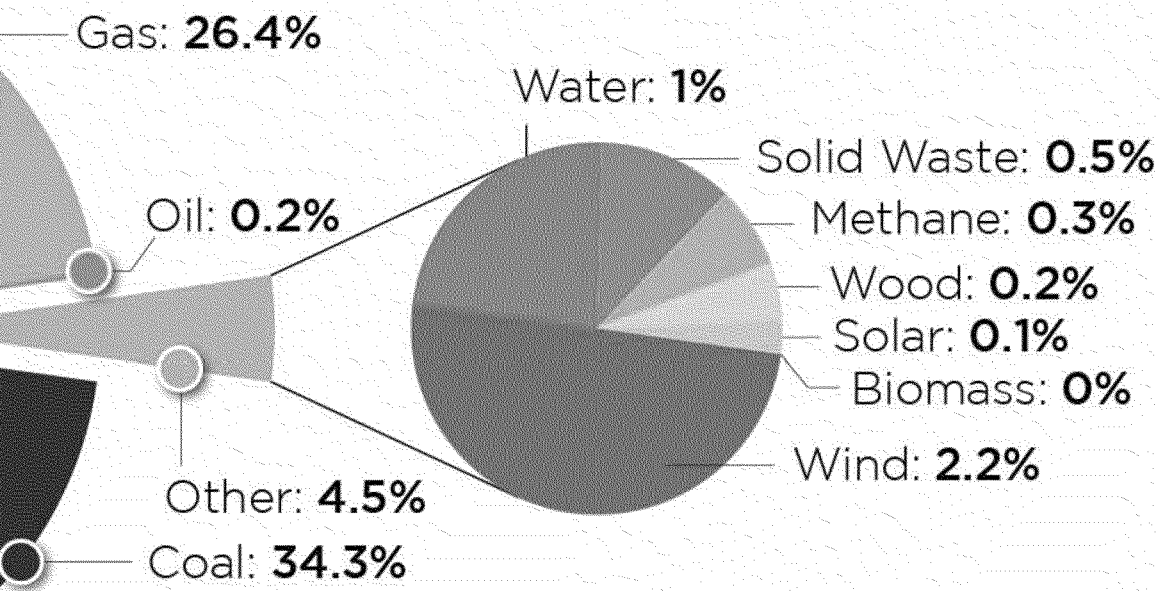

* Source: Monitoring Analytics, LLC. *2016 State of the Market Report for PJM*. Mar. 9, 2017.

# Focus

- Define resource diversity
- Define reliability attributes and measure capabilities of different resource types to provide these attributes
- Analyze resource diversity trajectory and potential impacts on reliability


pjm
Nuclear: 34.7%

# Variety & Balance



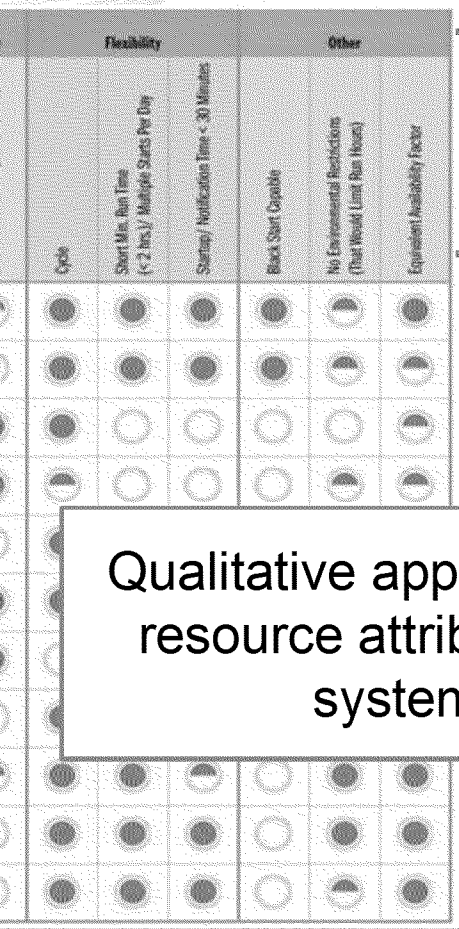

(% Annual Energy)

Contribution of each resource type to a particular attribute

● = Exhibits Attribute
◓ = Partially Exhibits Attribute
○ = Does Not Exhibit Attribute

| Resource Type | Essential Reliability Services (Frequency, Voltage, Ramp Capability) | | | | | Fuel Assurance | |
|---|---|---|---|---|---|---|---|
| | Frequency Response (Inertia & Primary) | Voltage Control | Ramp | | | | |
| | | | Regulation | Contingency Reserve | Load Following | Not Fuel Limited (> 72 hours at Eco. Max Output) | On-site Fuel Inventory |
| Hydro | ● | ● | ● | ● | ● | ○ | ◓ |
| Natural Gas - Combustion Turbine | ● | ● | ◓ | ● | ◓ | ● | ○ |
| Oil -Steam | ● | ● | ● | ● | ● | ● | ● |
| Coal - Steam | ● | ● | ● | ● | ● | ● | ● |
| Natural Gas - Steam | ● | ● | ● | ● | ● | ● | ○ |
| Oil/ Diesel - Combustion Turbine | ● | ● | ○ | ● | ○ | ○ | ● |
| Nuclear | ◓ | ● | ○ | ○ | ◓ | ● | ● |
| Battery/ Storage | ◓ | ◓ | ● | ● | ○ | ○ | ○ |
| Demand Response | ○ | ○ | ◓ | ◓ | ◓ | ◓ | ◓ |
| Solar | ◓ | ◓ | ○ | ○ | ◓ | ○ | ○ |
| Wind | ◓ | ◓ | ○ | ○ | ◓ | ○ | ○ |

# Essential Reliability Attributes

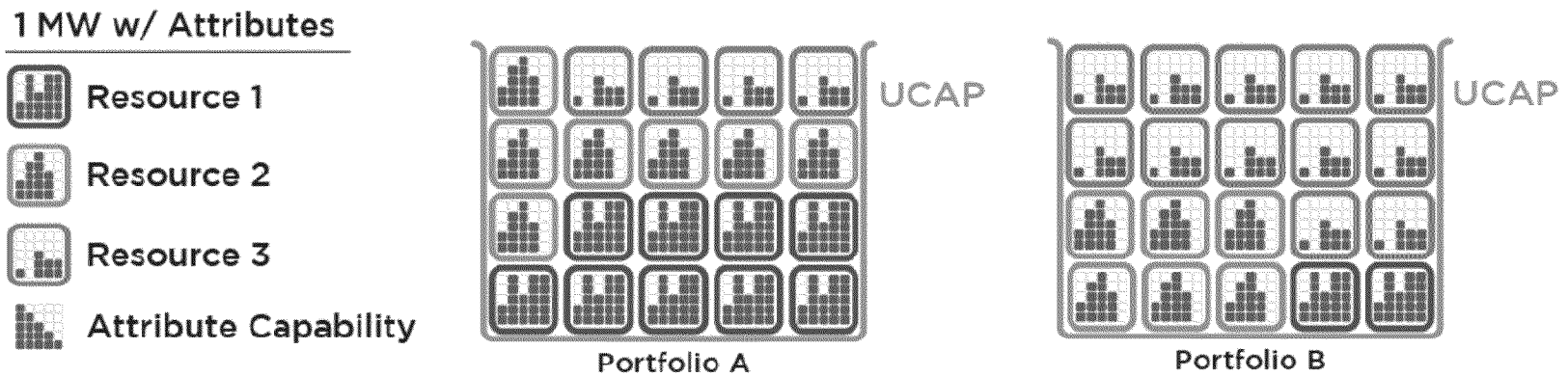


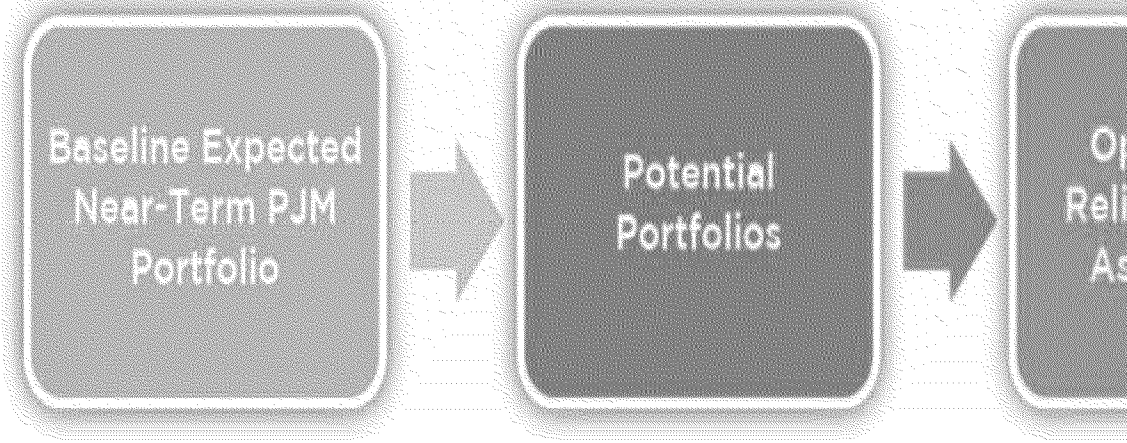

Capabilities needed by the grid to ensure reliability

Qualitative approach to describing resource attributes essential for system reliability

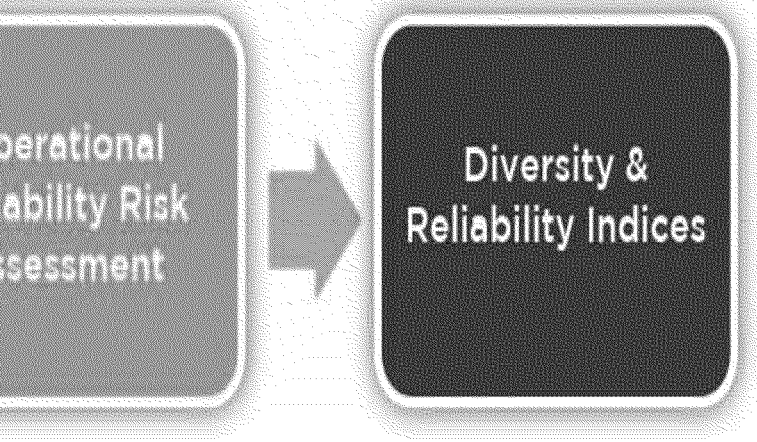
# Specific Reliability Attributes

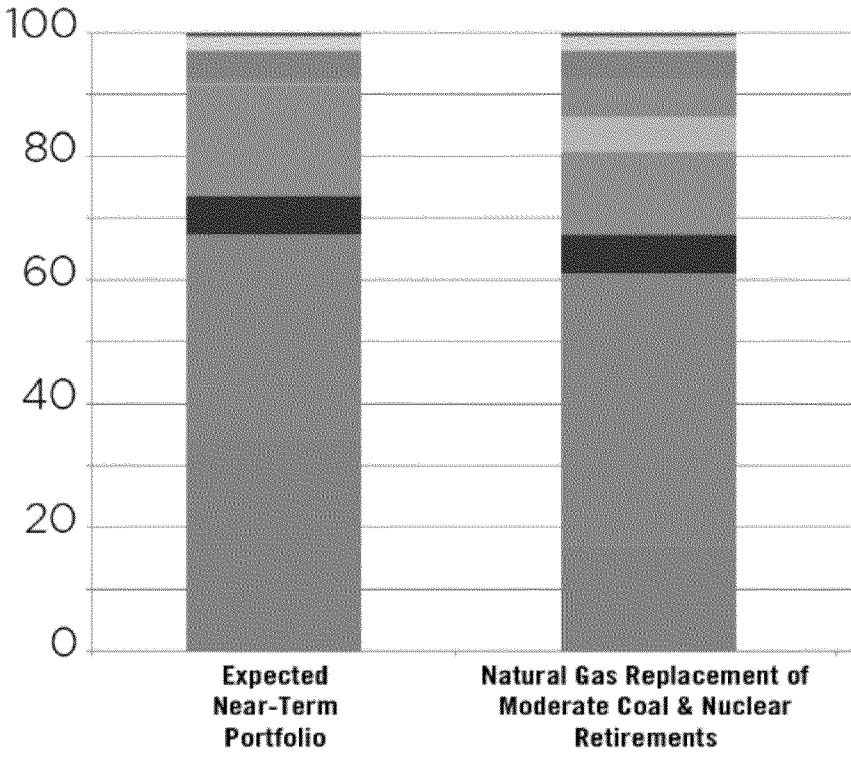
Different resource types have different operational characteristics that aid in maintaining system reliability



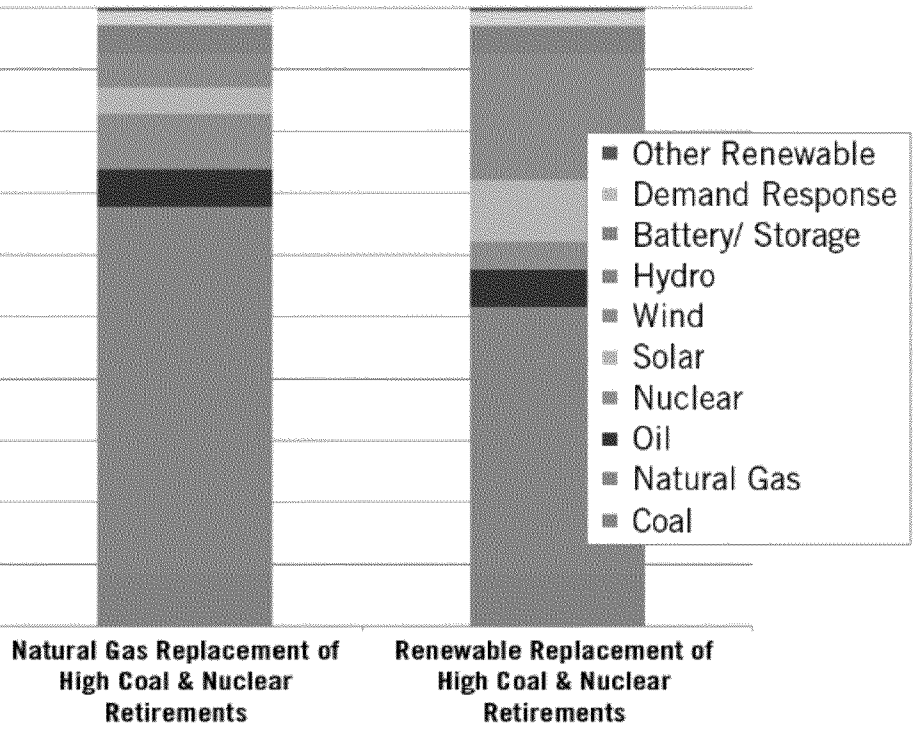


# Approach

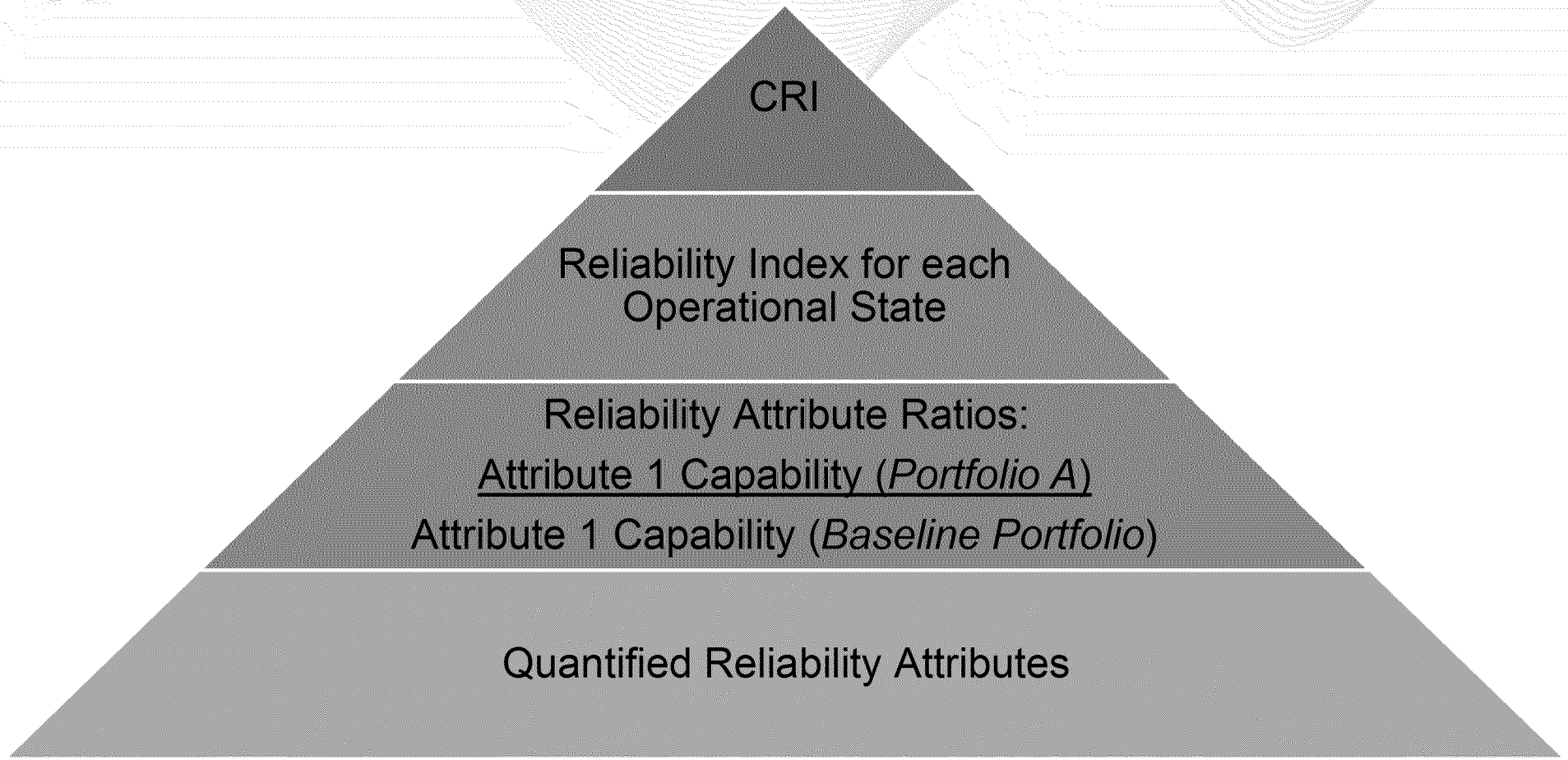



100
80
60
40
20
0
Expected Near-Term Portfolio
Natural Gas Replacement of Moderate Coal & Nuclear Retirements

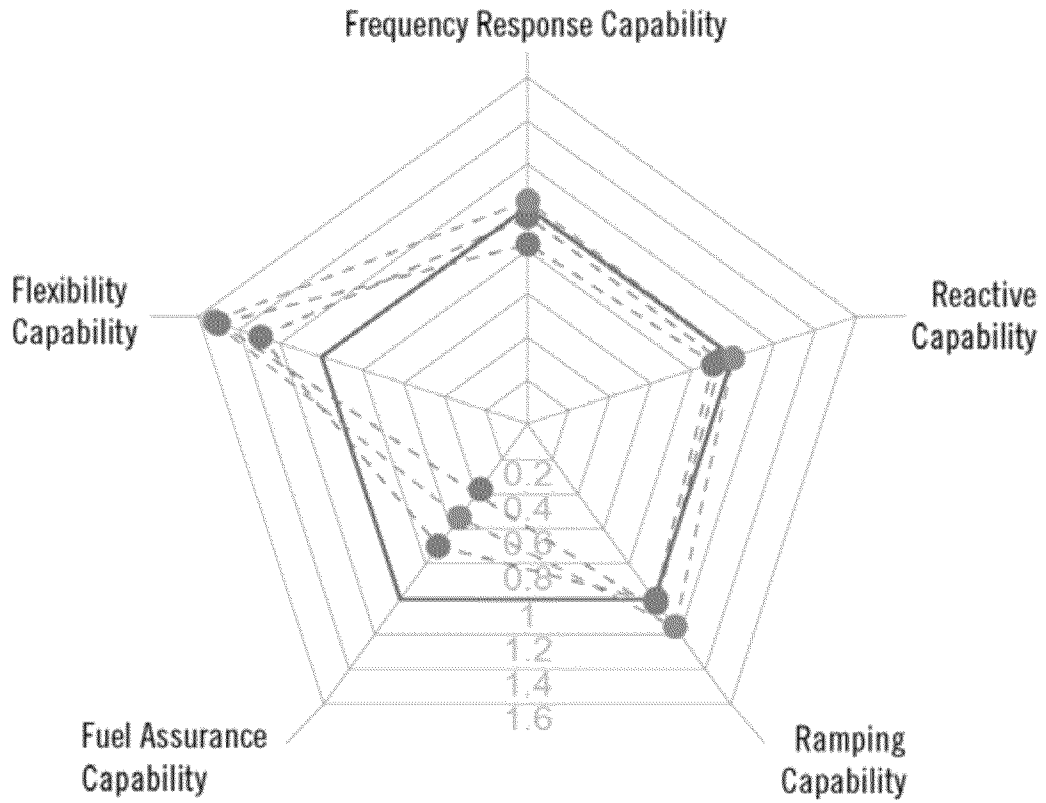
# Establish Portfolios



# Composite Reliability Attribute

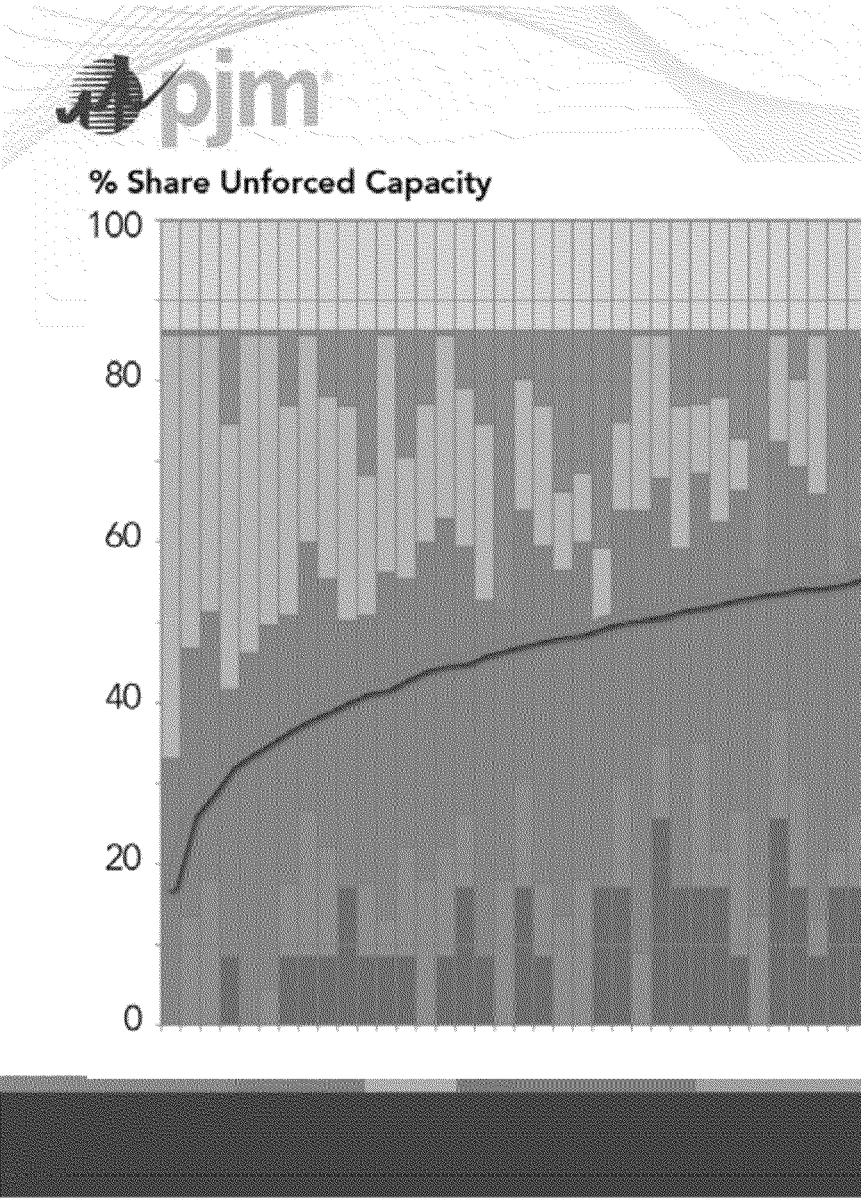


# Findings - Reliability Attribute Capability

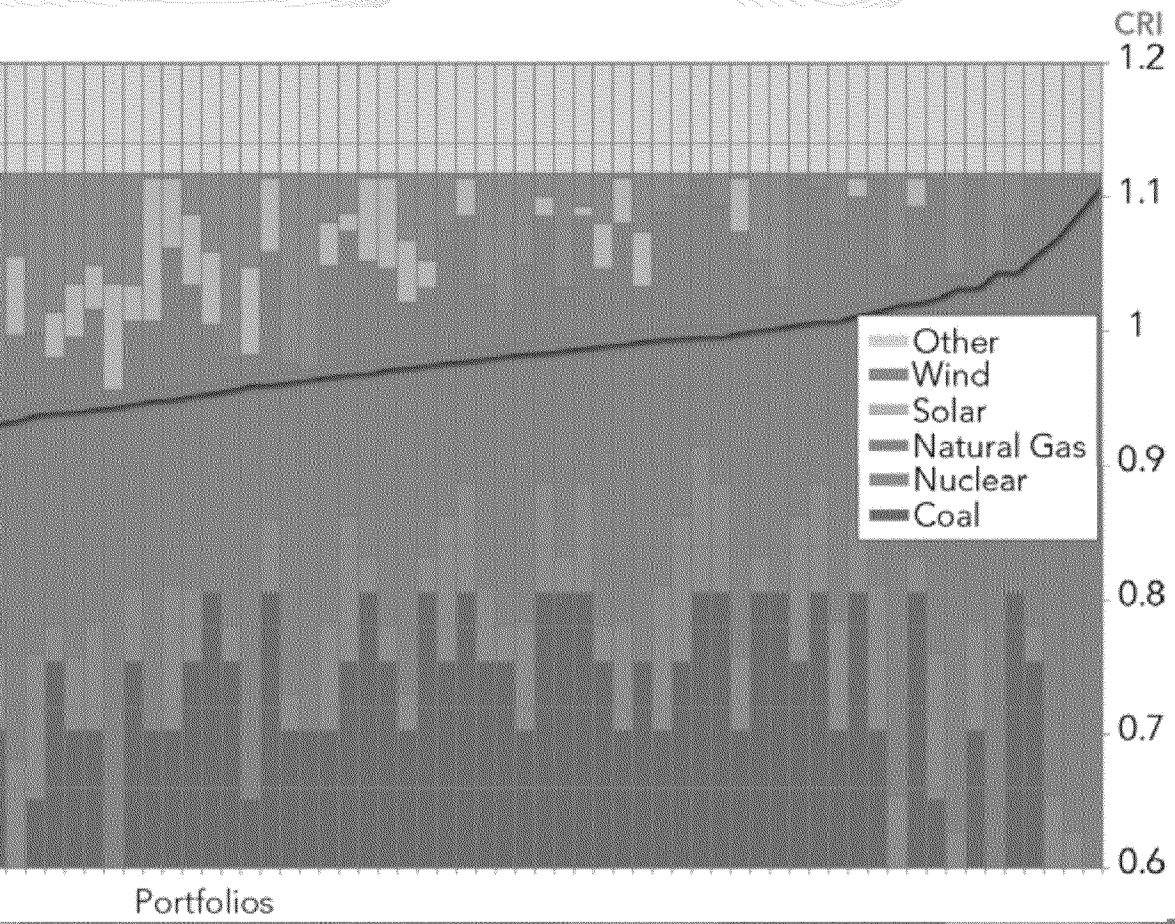


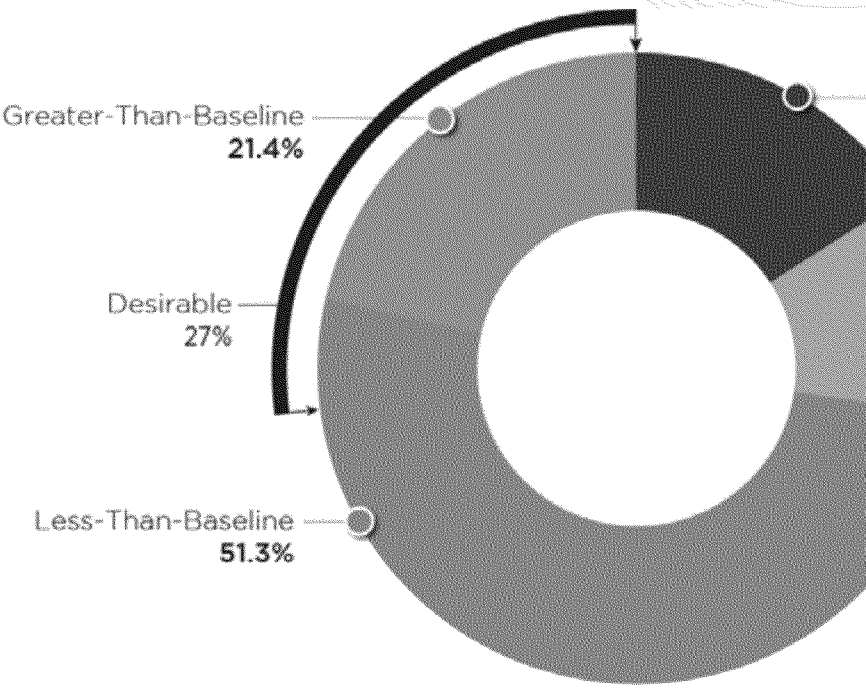

- Expected Near-Term Portfolio
- Natural Gas Replacement of Moderate Coal & Nuclear Retirements
- Natural Gas Replacement of High Coal & Nuclear Retirements
- Renewable Replacement of High Coal & Nuclear Retirements

Illustrative Future Portfolios


% Share Unforced Capacity
100
80
60
40
20
0

# Findings – Reliability Index




Greater-Than-Baseline
21.4%
Desirable
27%
Less-Than-Baseline
51.3%

# Distribution of Results


CRI Values by Portfolio Category

| Performance Category | Min | Max | LOLE Criterion |
|---|---|---|---|
| Infeasible | - | - | Failed |
| At-Risk-for-Under Performance | 0.79 | 0.90 | Met |
| Less-Than-Baseline | 0.90 | 0.99 | Met |
| Greater-Than-Baseline | 1.00 | 1.11 | Met |
| Desirable | 0.95 | 1.11 | Met |

# Findings - Impact of Diversity