PJM's Evolving Resource Mix and System Reliability

Rich Brown
Manager, Emerging Markets
PJM Interconnection
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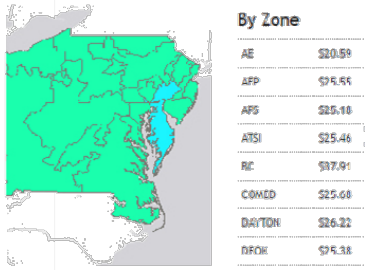
PJM as Regional Transmission Organization (RTO)

OPERATIONS

Matches supply with demand like...

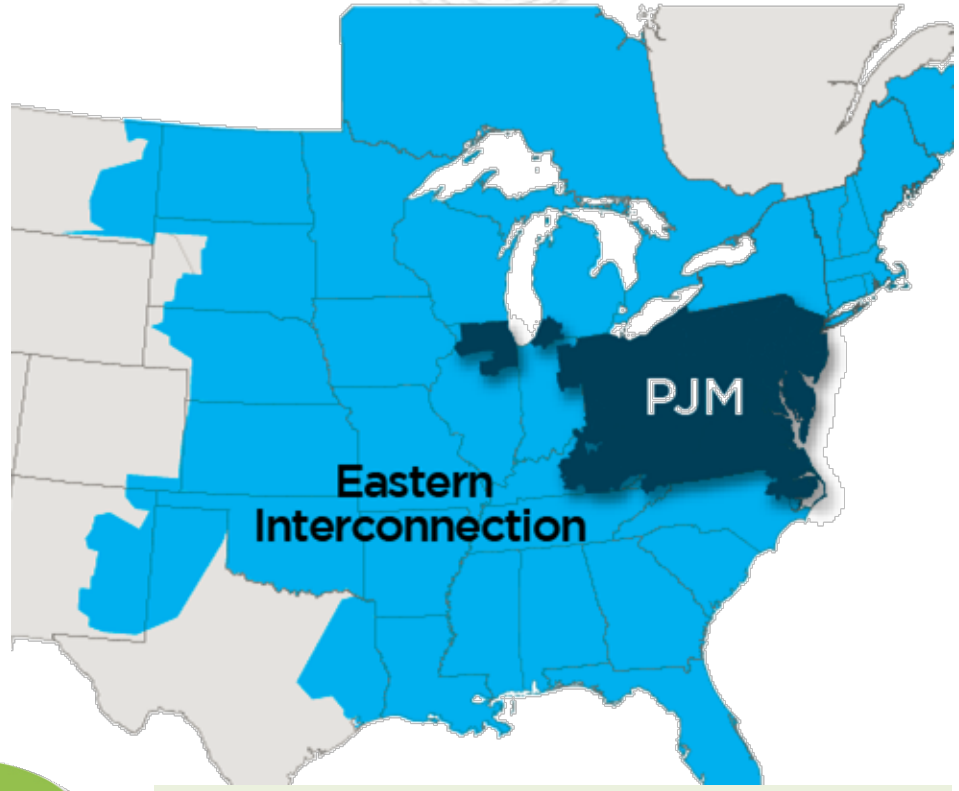
MARKETS



Energy Market Pricing like...

PLANNING

Planning for the future like...



- 61 million people served
- 21% of U.S. GDP
- 165 GW peak load

Industry Evolution

Evolution of Supply

- Traditional resources

Less flexible

- Renewable resources

Variable

- Coal to gas fuel transition, introduces coordination issues

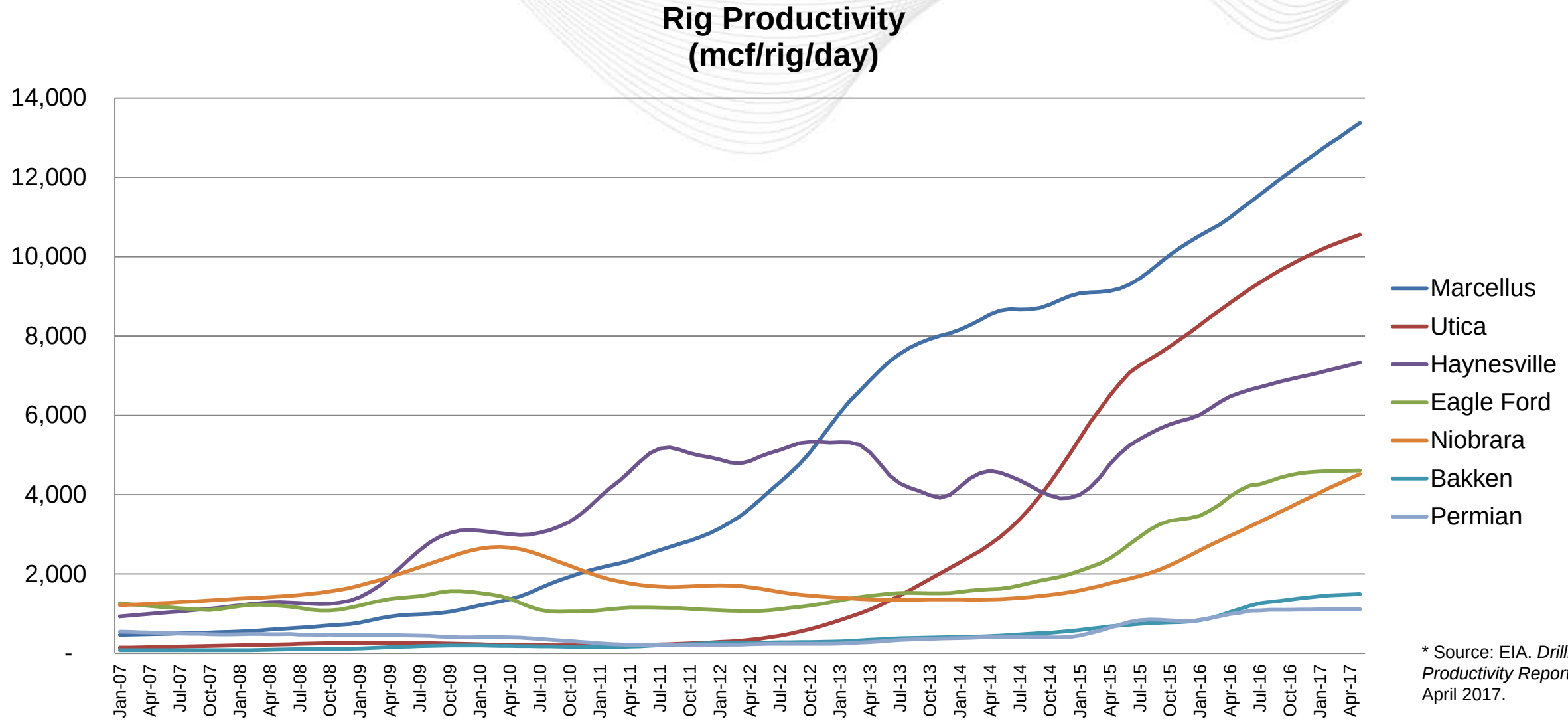
Evolution of Demand

- Technology enabled flexibility
- Alternative and distributed resource growth
- Opportunities for aggregated distributed resources to provide grid services

Market Evolution

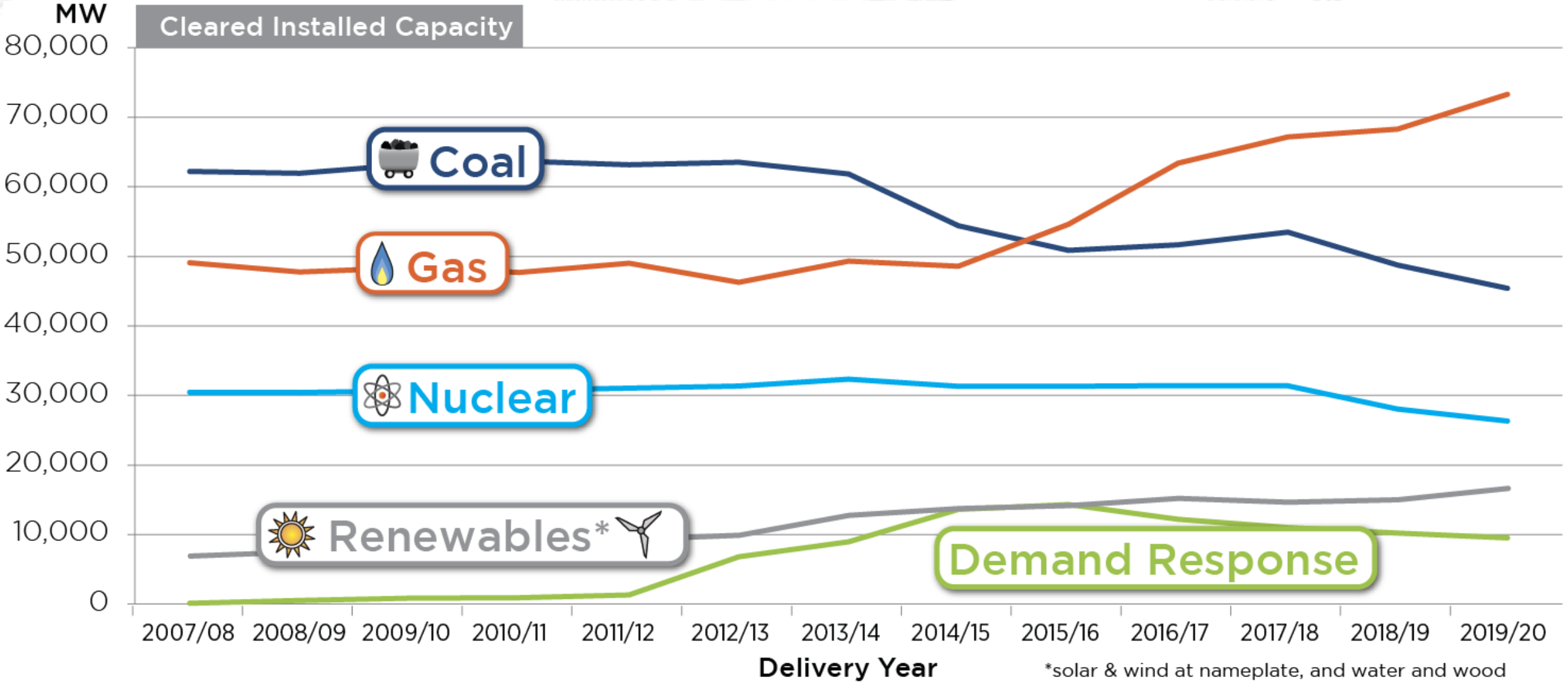
- Improvement in optimization and control systems
- More real-time markets to reward consumer flexibility
- Development of alternate resource / demand response control signals

Main Driver: Natural Gas



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

Capacity Market Managing Change



Fuel Diversity Summary

FOCUS

Define fuel diversity and fuel security with a primary focus on reliability

Analyze fuel diversity trajectory and identify avoidance areas which will negatively impact reliability

Reflect on current makeup of PJM / U.S. fuel diversity

Explore fuel security and impact on reliability and fuel diversity

APPROACH

1. **Leveraged NERC Essential Reliability Services** to measure reliability
2. **Establish Baseline** near-term PJM portfolio
3. **Establish Potential Portfolios**
4. **Operational Reliability Risk Assessment**
5. **Diversity & Reliability Indices**

FINDINGS

Portfolios composed of up to 86 percent natural gas showed no decreases in reliability but increase risk in fuel security.

Portfolios with moderate wind/ solar are reliable if accompanied by large shares of coal and natural gas.

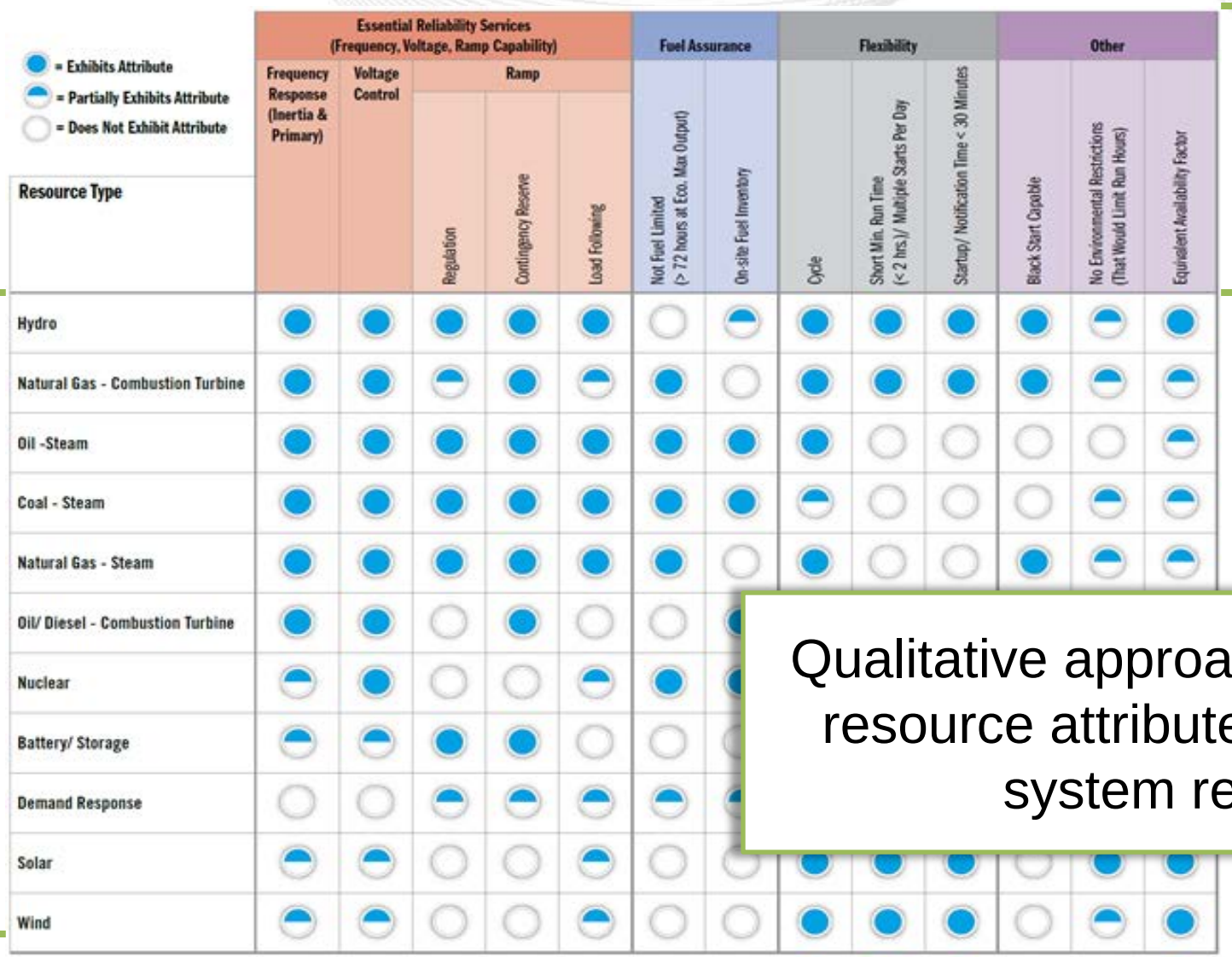
As the resource mix moves in the direction of less coal and nuclear generation, frequency response, reactive capability and fuel assurance attributes decrease.

Essential Reliability Attributes

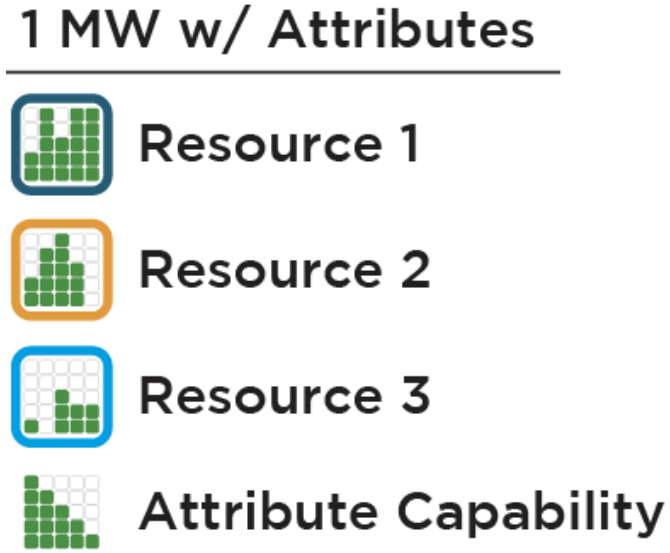
Capabilities needed by the grid to ensure reliability

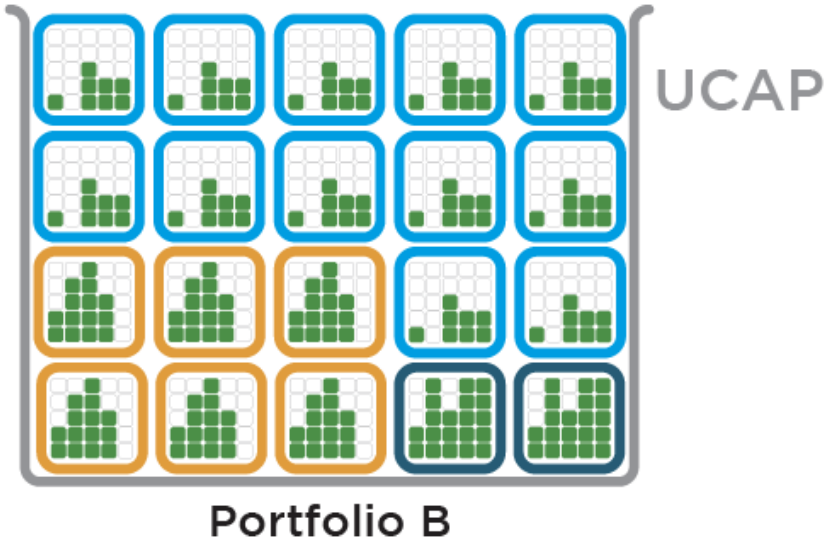
Contribution of each resource type to a particular attribute

Qualitative approach to describing resource attributes essential for system reliability



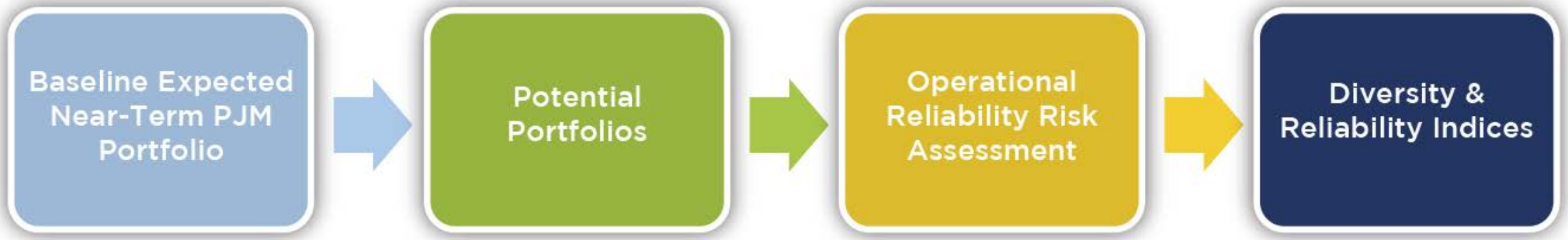
Generator Reliability Attribute Primer



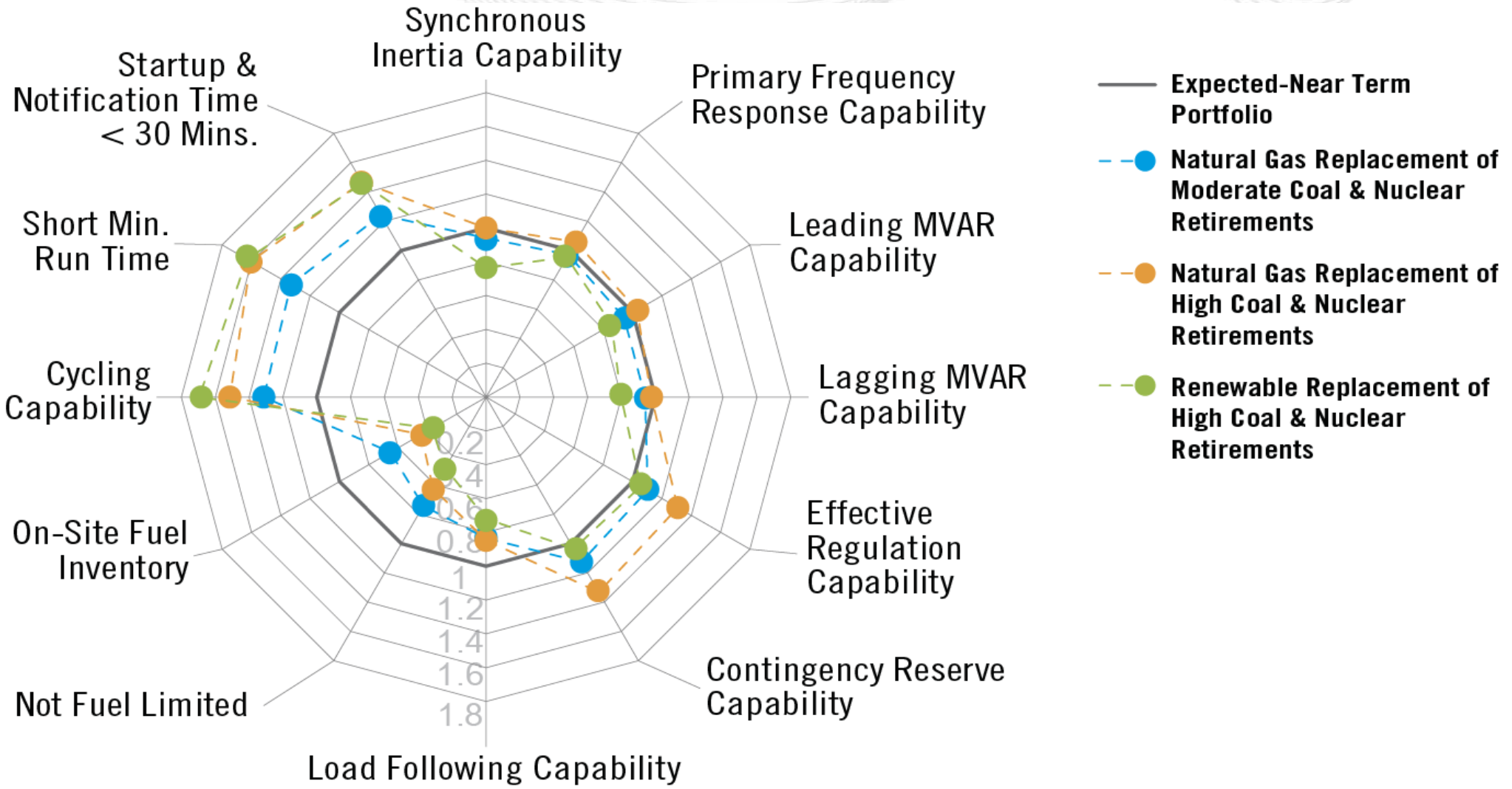


Unforced capacity (UCAP) – MW, value of a capacity resource in the PJM Capacity Market, which accounts for a resource's availability

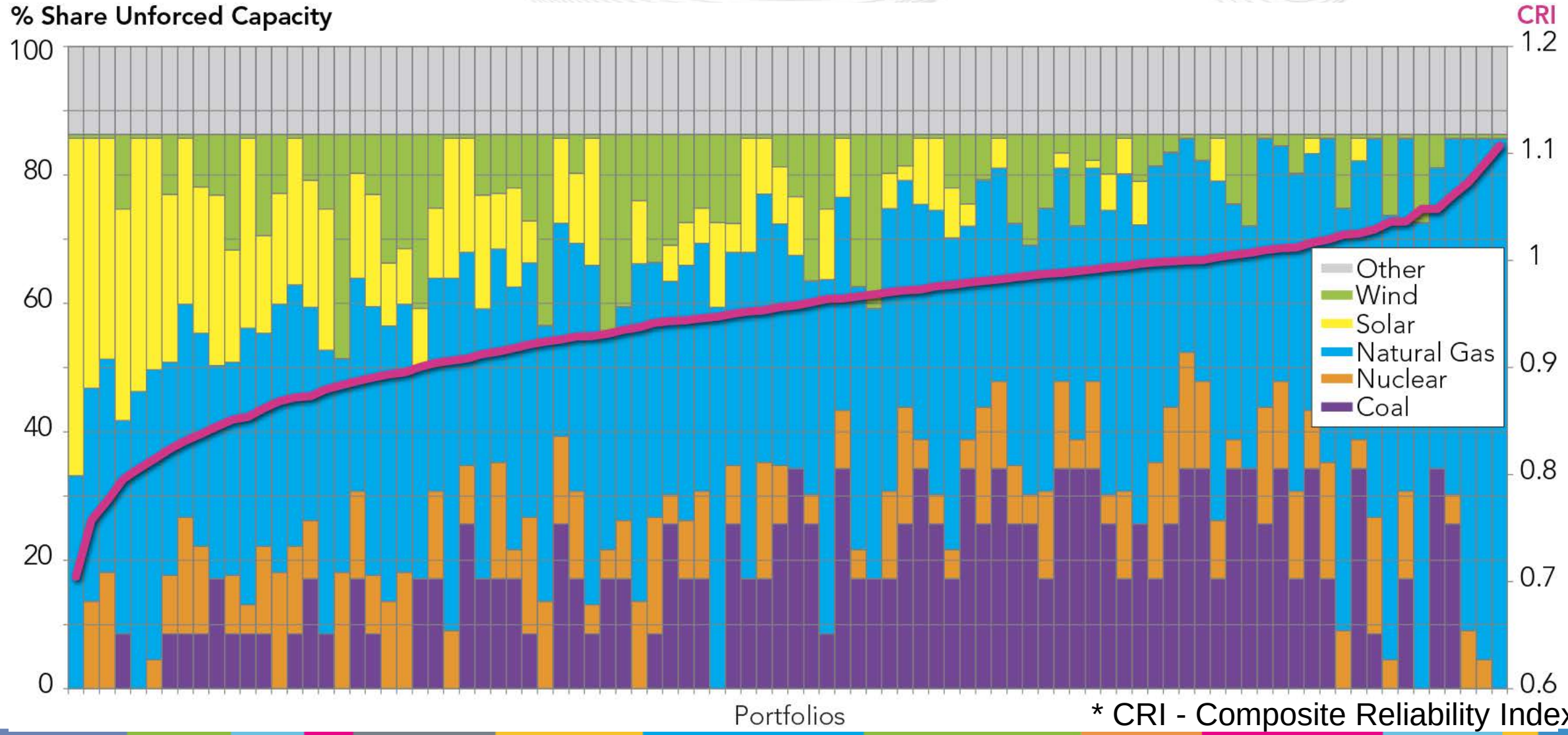
Fuel Security Risk Analysis



Generator Reliability Attributes in Changing Portfolios – Individual Reliability Attribute Ratios

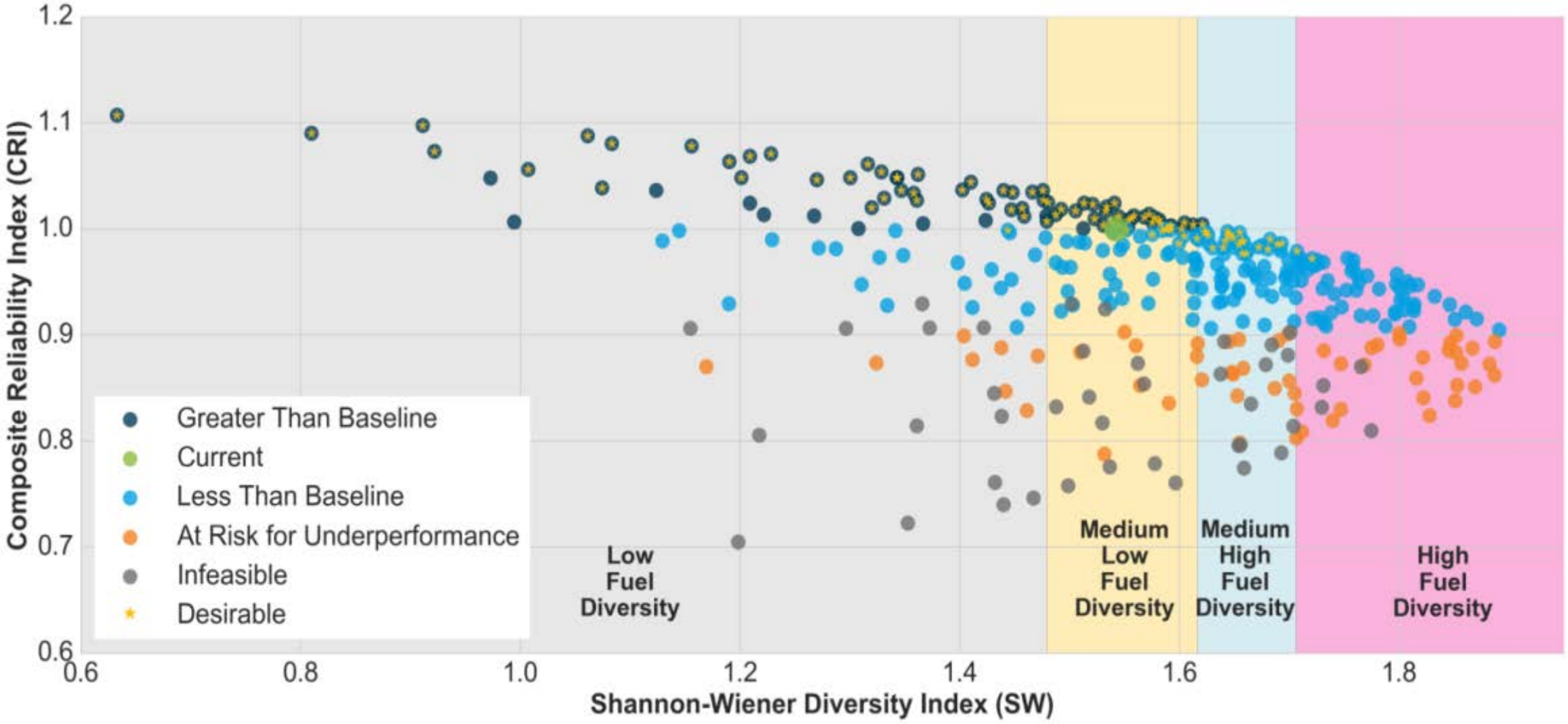


Diversity Mix Results

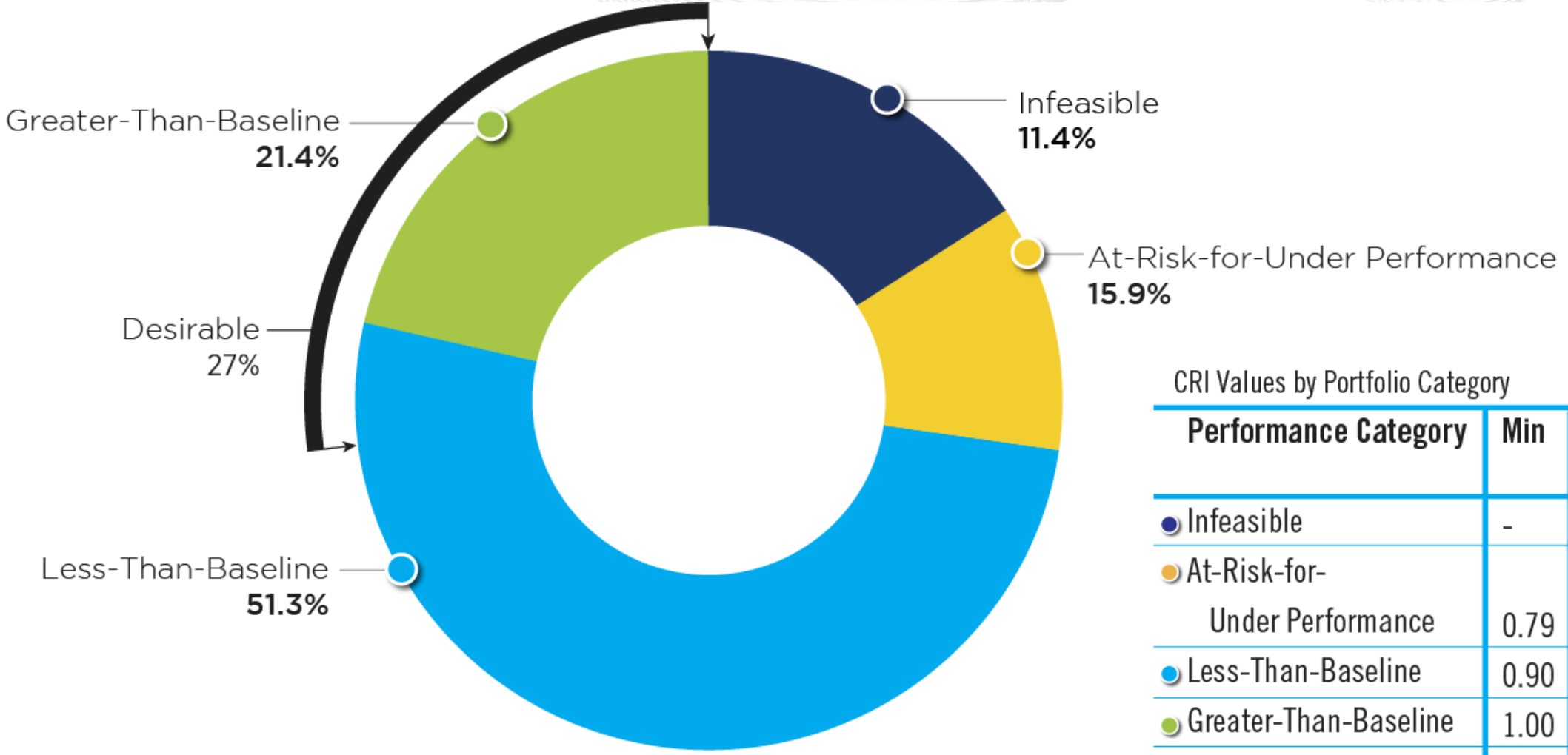


* CRI - Composite Reliability Index

CRI vs. Shannon-Wiener Diversity Index



Distribution of the Performance Categories



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

Reliability… Resilience

Risks / Dependencies:
Extreme Weather | Physical/Cyber Attacks | Fuel Source/Security

	Prepare	Operate	Recover
CURRENT	**Build New Infrastructure** • RTEP: locational, criticality • Supplemental: aging infrastructure, local needs **Physical & Cyber** • Protect critical infrastructure • Drills with members, industry • Design for security	**Operations** • Operate to manage equipment failure • Study pipeline, other contingencies **Physical & Cyber** • Monitor & reduce vulnerabilities • Threat info. sharing	**Operations** • Blackstart **Physical & Cyber** • BCP Plans & Golden Image • Coordinate with Gov't/industry • Cyber mutual assistance
FUTURE	**Build New Infrastructure** • Resilience as a driver **Installed Reserves** • Incorporate risks in reserve margin	**Operations** • Operate to manage additional risks - Expand contingencies & operating reserves **Markets** • Value flexible resources beyond reliable criteria **Leverage Alternative Technologies** • Microgrids & DER	**Operations** • Assess vulnerabilities in Blackstart plans **Alternative Technology** • Using alternative technology for Blackstart

So where does that take us?

Continuing improvement in gas / electric coordination – including resilience

Valuing these and potentially other essential resource attributes into the future?

Looking at resilience in planning and operations in addition to reliability