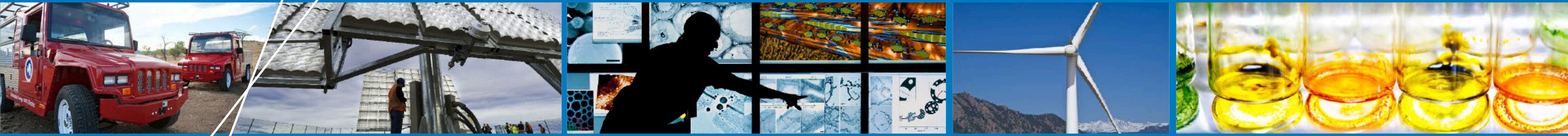
Options Impacting the Electric System of the Future (ESF)



Karlynn Cory

August 10, 2015

Denver, Colorado

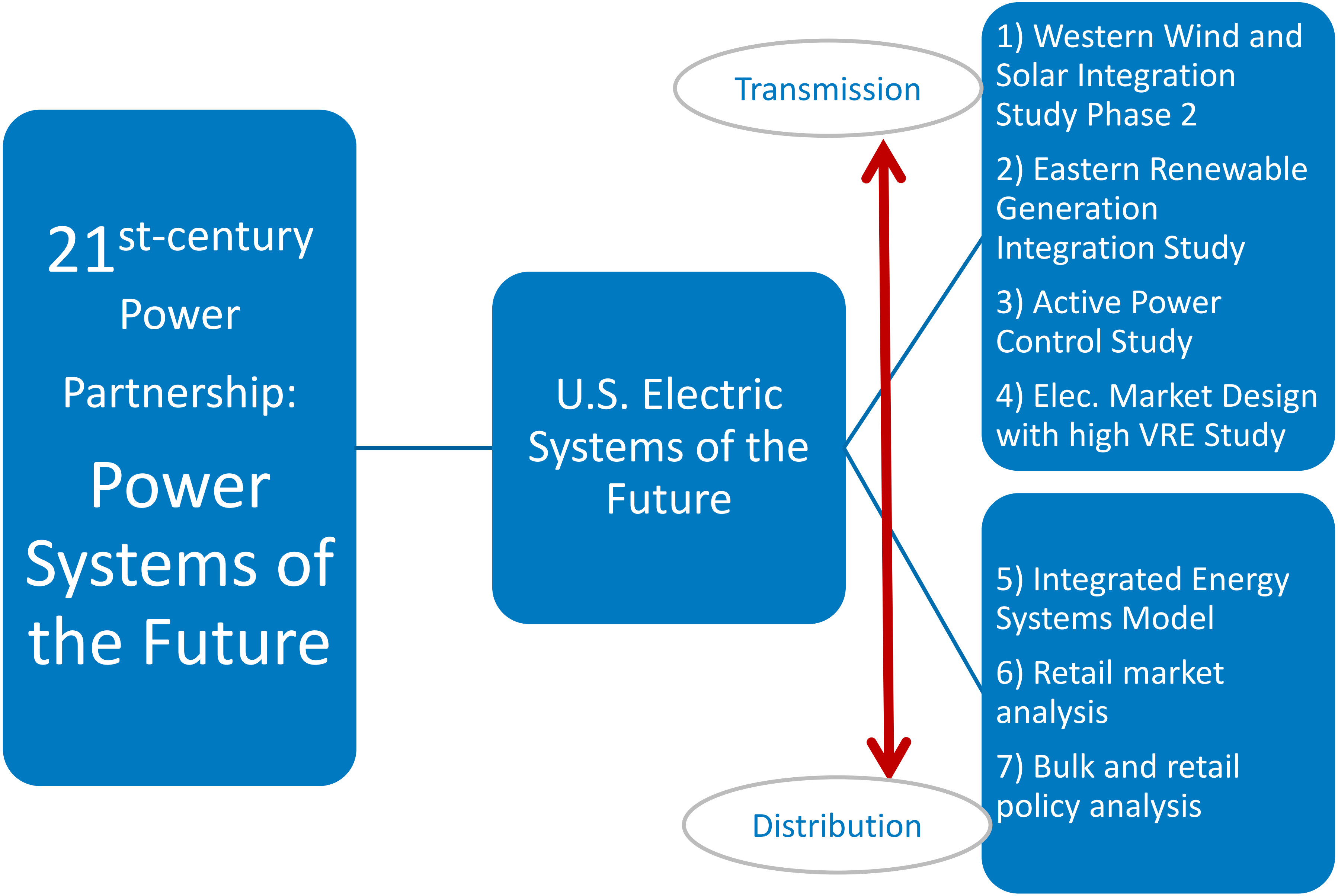
EUCI Conference – Utility 2.0: Adapting to the New Business Reality

Session: Pathways for Converting the Promise of the Intelligent Grid into Value for Utilities and Consumers

NREL/PR-6A20-64778

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

NREL Research: Electric Sector Transformation



U.S. Electric Systems of the Future – Executive Summary

- **U.S. electric sector is changing:**
  1. Increased amounts of variable renewable energy,
  2. Deployment of distributed energy resources, and
  3. Increased interactivity of the grid (T & D) and between utilities and consumers.
- **Goal of the Effort:**
  - Identify analysis needs in the near term for providing electric sector analysis to examine the transformation of institutions, technology, and integrated systems.
  - Identify where NREL's capabilities fit the needs
- **Two tasks accomplished:**
  1. Created a thought framework that captures emerging disruptions and how today's investments will drive different U.S. electricity future directions
  2. Identified elements of analysis needs that will inform key aspects of the different future directions:
     - A. Identify ways to include risk and uncertainty in state regulations and competitive market rules
     - B. Assess DER penetration and how it impacts utility business models, planning, and operations.

Photo by Warren Gretz, NREL 08024

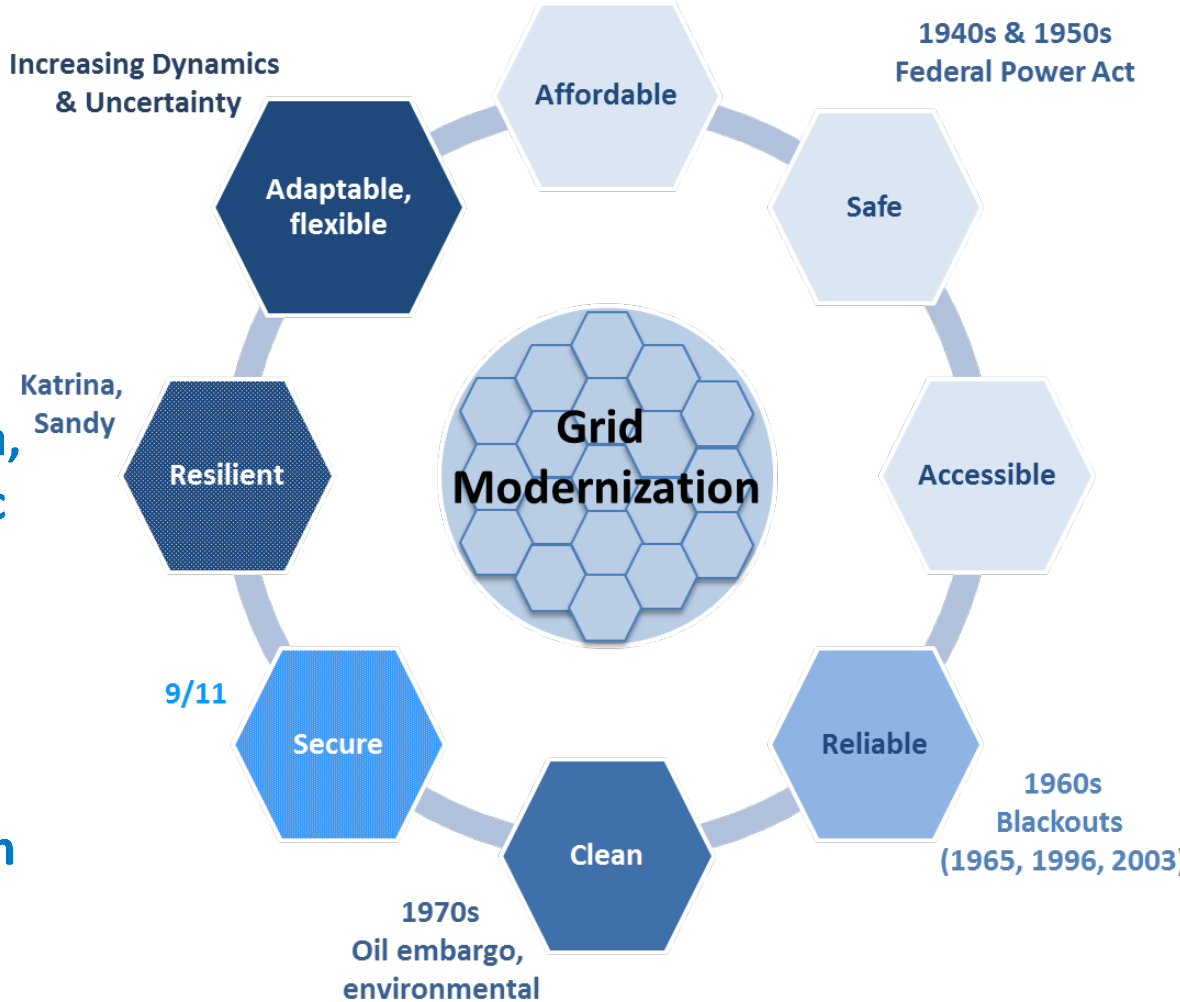
Photo by iStock/7148505

Photo by Patrick Laney, NREL 13080

Background

Grid Modernization Must Support 8 Key Attributes

- DOE Grid Tech Team (GTT) has identified eight key attributes that must be designed into a modernized grid.
- The relative balance among the attributes will vary from region to region, but all are essential public goods.
- The attributes are interactive and reinforcing. Pursuing a subset with little attention to others will be ineffective.

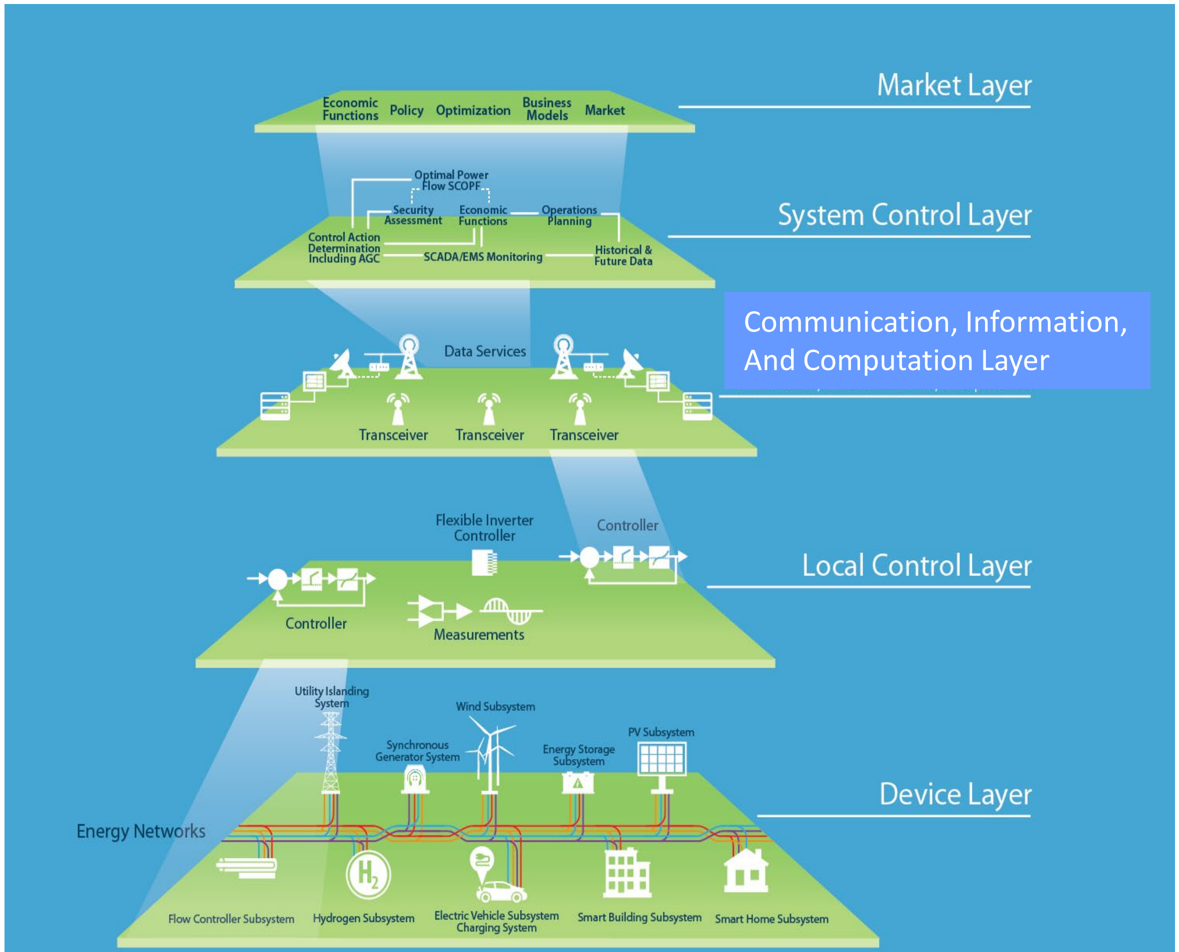


Background

Electric Systems of the Future and Energy Systems Integration

- Technology, economics, policy and regulatory structure will drive detailed interfaces below. **Institutional factors & business cases are critical (market layer)**
- Education at all levels is a pre-requisite for achieving this (and related) futures

Electric Systems of the Future



Energy Systems Integration (ESI) R&D

Future Outlook

Five Vastly Different Future Directions

Business as Usual

- Goal: replace aging assets with same, newer assets; meet existing fed/state policies
- Impact: Trans. grid improved, but not modernized (same updated equip.), increase carbon
- Tomorrow: central gen. dominates, slightly improved T interconnectivity (one-way system communications; some DER), same wholesale/retail markets, objective = least-cost

Low-Carbon, Centralized Generation

- Goal: replace aging generation w/low-carbon, centralized gen.: 1) utility-scale RE, 2) natural gas, 3) nuclear, and/or 4) clean coal; (but what can/will utility own differs by region)
- Impact: Slower/decreased carbon output; some DER; curtailment likely; better Trans. grid
- Tomorrow: Low-carbon, centralized generation dominates in 20 years, improved T interconnectivity, updated 5-min. markets, objectives = lowest risk, lowest carbon

Rapid Growth of DER

- Goal: Growth of distributed energy resources (DER: non-dispatchable DG, distr. storage)
- Impact: Shift towards DG PV (primarily) and storage; some distribution grid improvements
- Tomorrow: Measurable energy and capacity needs met with DER in 20 years, improved D interconnectivity, updated wholesale/retail markets, objective = resilience

Interactivity: Grid and Demand

- Goal: Fully interactive T&D grid and substantial interactive demand (including DR) in 20 yrs
- Impact: Fully optimized, communicating, and modernized T&D grids (planning and ops)

Tomorrow: Max. grid flexibility (gen., loads, storage, new T&D, power systems ops.); updated wholesale /retail markets; Consumer control; objectives=grid flexibility, consumer desires

Grid Defection

- Definition: Past a tipping point – measureable grid defection in next 20 years;
- Impact: Rising costs (same cost over fewer customers) leads to more defection;
- Tomorrow: consumers tired of escalating electricity rates, so decide to disconnect from the grid. Assumes full grid defection (not using grid as backup)

Important Note

- **Futures on previous page are not exclusive**
- **In reality, a mix of futures will emerge**
- **Defining key futures separately, helps one:**
  - Understand the particular needs of emphasizing a particular direction,
  - Identify key barriers and enablers that intersect in multiple futures, and
  - Understand how choices made today can leave open or shut off options in the future.

Future Outlook

Future Directions – Mapped to Disruptions

Emerging Disruptions / Drivers	Low-carbon centralized	Rapid Growth of DER	Interactivity: Grid & Demand
Improved electric system flexibility	X	X	X
Financing opportunities	X	X	X
Technology improvements	X	X	X
Carbon policies (e.g. 111(d), tax)	X	X	
Limited NG expansion	X	X	
Transmission planning	X		X
Transmission cost allocation	X		X
Bulk power market updates	X		X
Valuation of new services		X	X
Ownership opportunities		X	X
Local concerns about resilience		X	X
Electrification of transportation		X	X
Policies supporting DER		X	
Improved/new control systems			X

Deliverable #2

Thought Framework: Disruptions → Future Directions Detail

EMERGING DISRUPTIONS

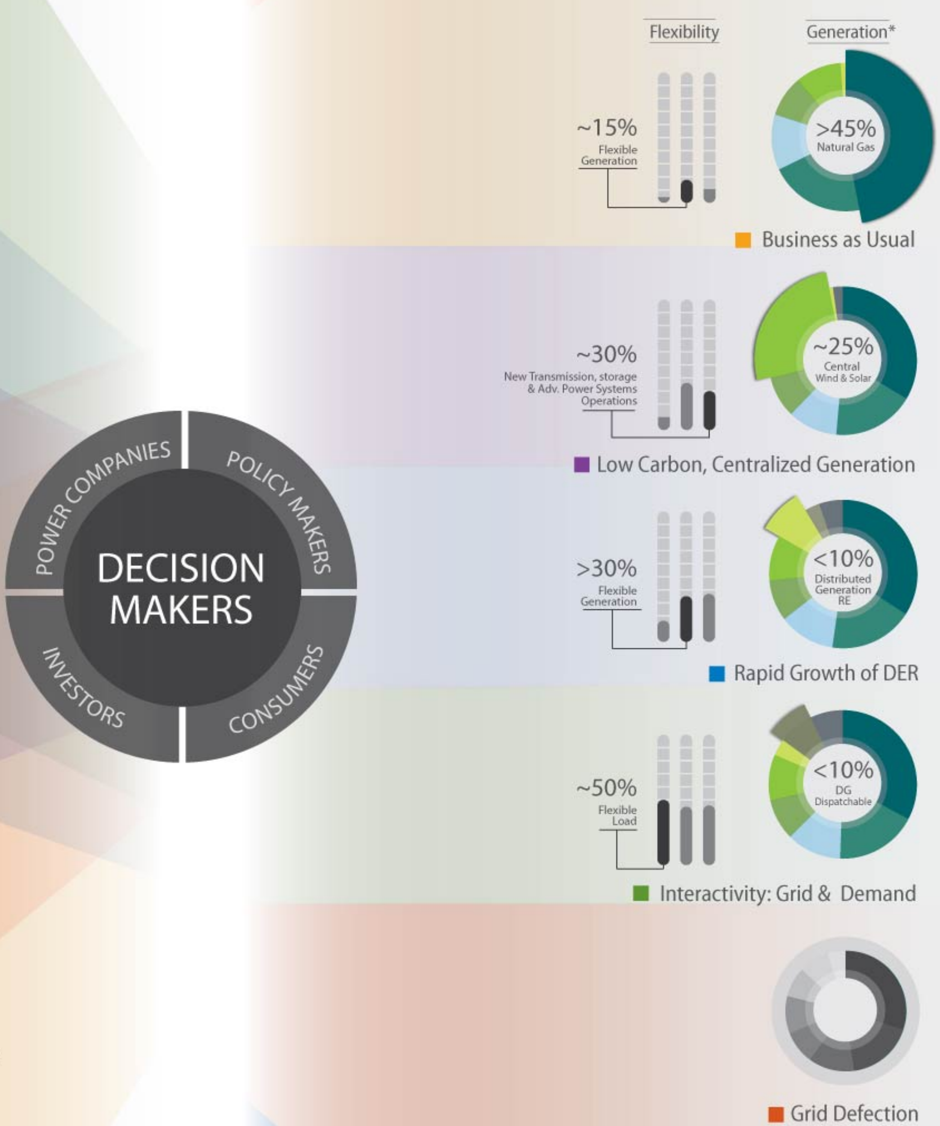
TECHNOLOGY
- Technology Improvements
- Improved flexibility management (technical aspects)
- Electrification of the transportation sector
- Cyber-attacks with long/widespread outages
- Physical disruptions with long/widespread outages (e.g. weather, attacks)

POLICY AND REGULATORY
- Final EPA Section 111 (d) rules
- National carbon market or carbon tax (policy)
- Policies to accelerate prevention of/recovery from cyber attacks
- Improved flexibility management (policies and regulations)
- Evolved regulations and policies focused on value of services
- Inability to, or high cost of interconnection
- Improved bulk system interconnections and sub-hourly markets

MARKET
- National carbon market or carbon tax (market)
- Improved flexibility management (market aspects)
- Evolved market rules focused on value of services
- Improved bulk system interconnections and sub-hourly markets

FINANCING
- Reduce capital uncertainties for clean generation (VRE, clean coal, nuclear), DG, bulk and distributed storage, value of services (flexibility, interactivity), and cyber-attack and physical disruption prevention
- Increased capital and financing for consumer-purchased resources
- Natural gas (NG) pipeline expansion limits, and NG fracking environmental restrictions

UTILITY BUSINESS MODELS
- Evolved business models focused on value of services
- Improved flexibility management (business aspects)
- Involvement of non-utilities (including third-party owners, customers) with different interests/business cases



*Generation Mix Key: Natural gas, Coal, Clean coal, Nuclear, Other Central RE, Central Wind & Solar, DG RE, DG dispatchable, Storage

Deliverable #2

Thought Framework: Disruptions → Future Directions Detail

EMERGING DISRUPTIONS

TECHNOLOGY
- Technology Improvements
- Improved flexibility management (technical aspects)
- Electrification of the transportation sector
- Cyber-attacks with long/widespread outages
- Physical disruptions with long/widespread outages (e.g. weather, attacks)

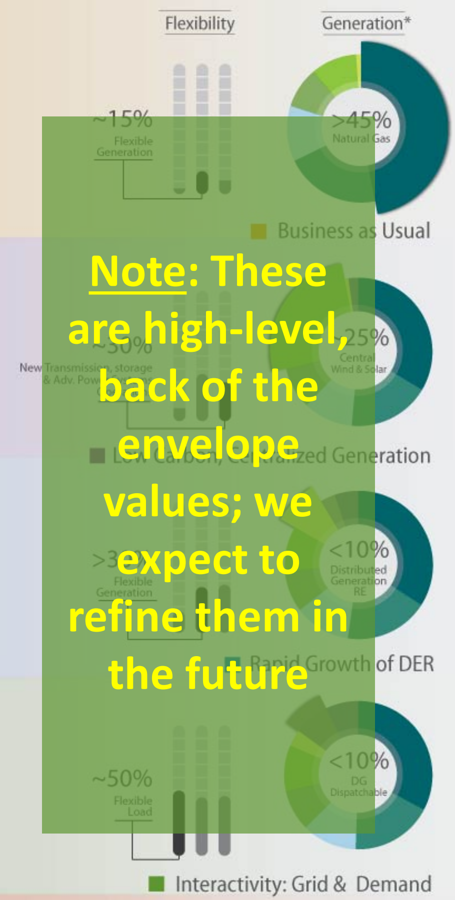
POLICY AND REGULATORY
- Final EPA Section 111 (d) rules
- National carbon market or carbon tax (policy)
- Policies to accelerate prevention of/recovery from cyber attacks
- Improved flexibility management (policies and regulations)
- Evolved regulations and policies focused on value of services
- Inability to, or high cost of interconnection
- Improved bulk system interconnections and sub-hourly markets

MARKET
- National carbon market or carbon tax (market)
- Improved flexibility management (market aspects)
- Evolved market rules focused on value of services
- Improved bulk system interconnections and sub-hourly markets

FINANCING
- Reduce capital uncertainties for clean generation (VRE, clean coal, nuclear), DG, bulk and distributed storage, value of services (flexibility, interactivity), and cyber-attack and physical disruption prevention
- Increased capital and financing for consumer-purchased resources
- Natural gas (NG) pipeline expansion limits, and NG fracking environmental restrictions

UTILITY BUSINESS MODELS
- Evolved business models focused on value of services
- Improved flexibility management (business aspects)
- Involvement of non-utilities (including third-party owners, cu… different interests/business cases

POTENTIAL FUTURES



Note: These are high-level, back of the envelope values; we expect to refine them in the future

- Many disruptions (e.g. flexibility), repeat across multiple success transformation categories listed
- Each disruption is linked to specific future directions

Grid Defection

*Generation Mix Key: Natural gas, Coal, Clean coal, Nuclear, Other Central RE, Central Wind & Solar, DG RE, DG dispatchable, Storage

Analysis Needs

To address the top analysis needs (DER impacts, and risk and uncertainty in policy making), the following analysis ideas appear to be first steps:

1. **Quantify the costs of BAU – compared to the other potential futures**
   - Do more precise analysis using Standard Scenarios as a baseline

2. **Create a decision tool, with probabilities, that will ask the user to decide about emerging disruptions and probabilities of different options – and will illuminate the likelihood of different future directions (and which options are not enabled)**

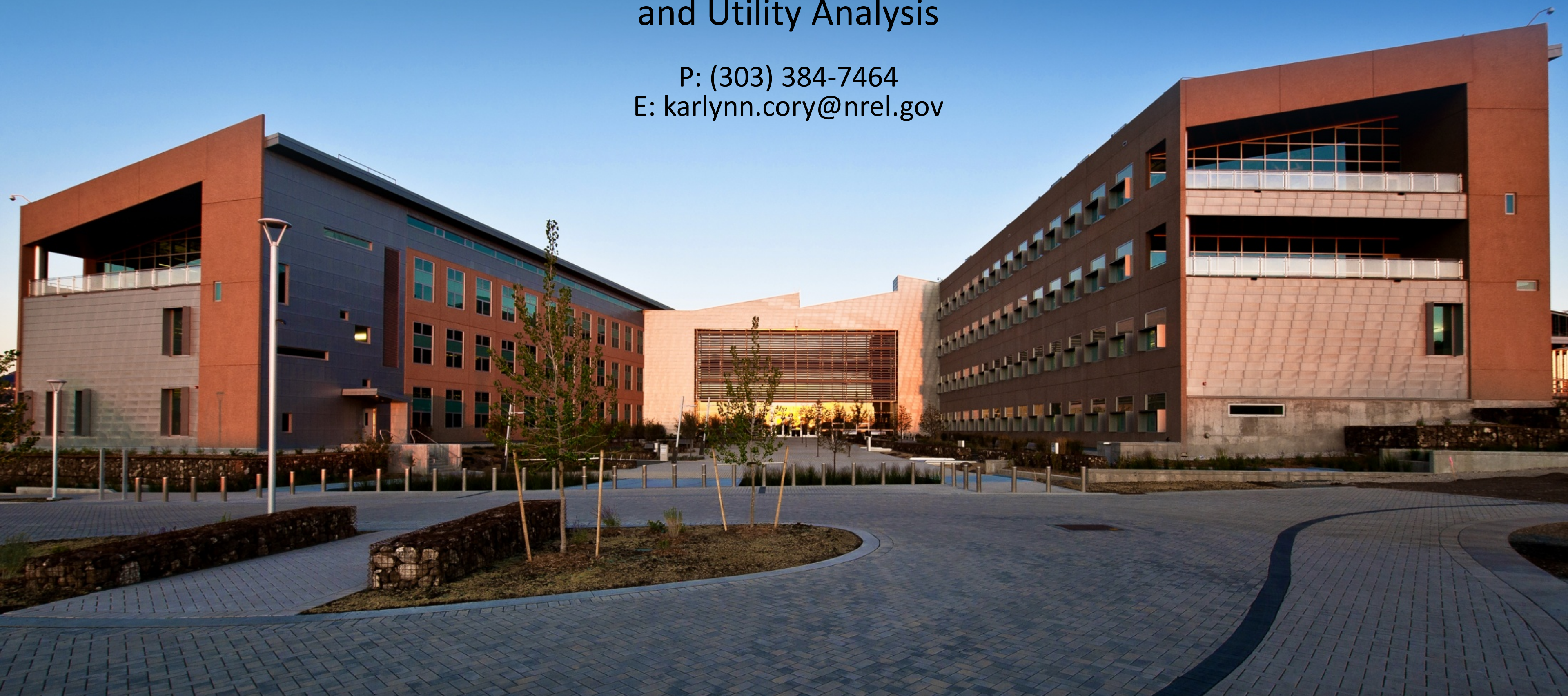
3. **Assess and quantify when stakeholders need to incorporate DG in their planning and operations, before high penetration impacts operations or business case.**

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Karlynn Cory

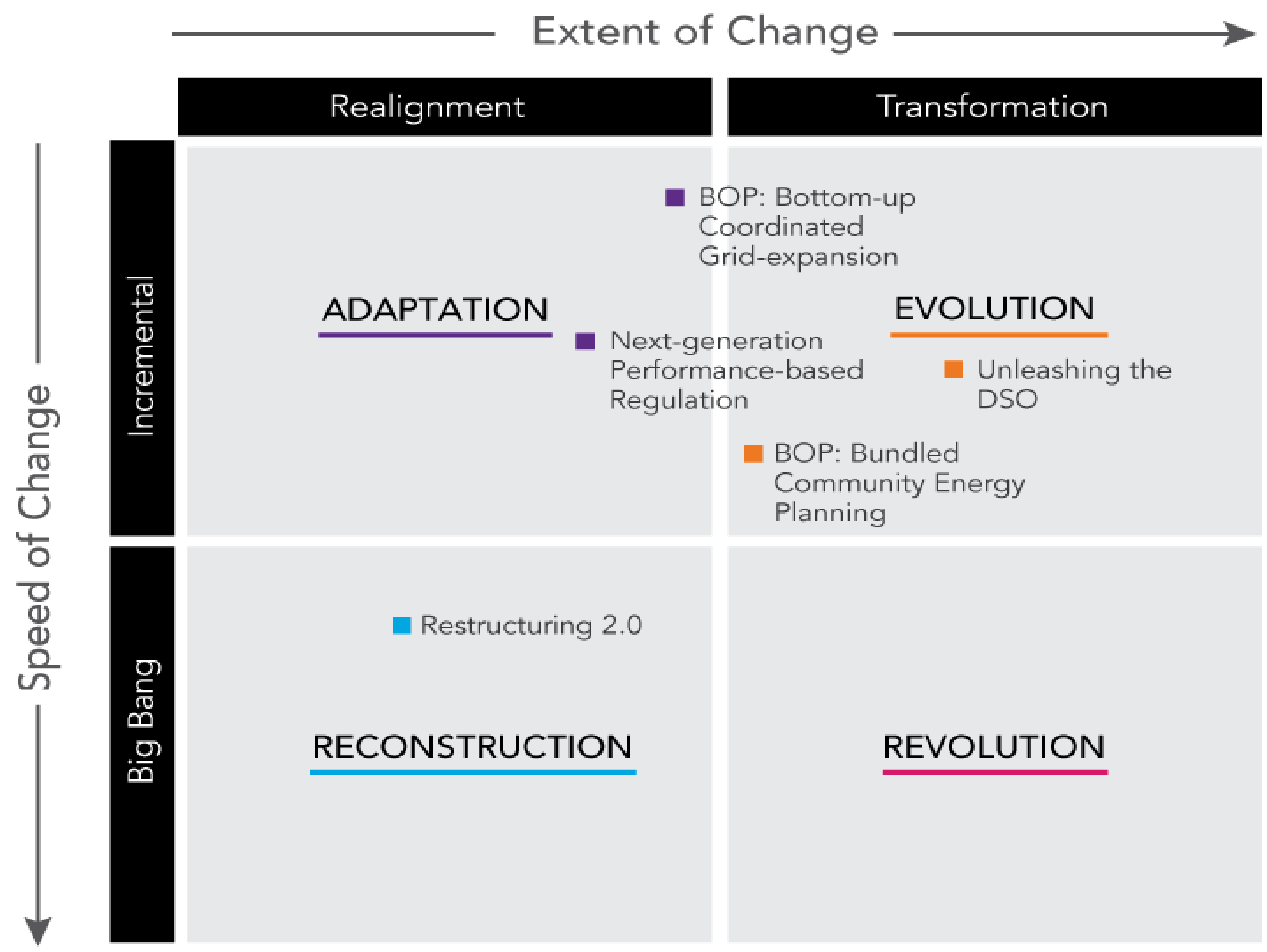
Manager – Technology Systems and Utility Analysis

P: (303) 384-7464
E: karlynn.cory@nrel.gov



International - 21st Century Power Partnership
Power Sector of the Future

Illustrative Landscape of Power System of the Future Pathways

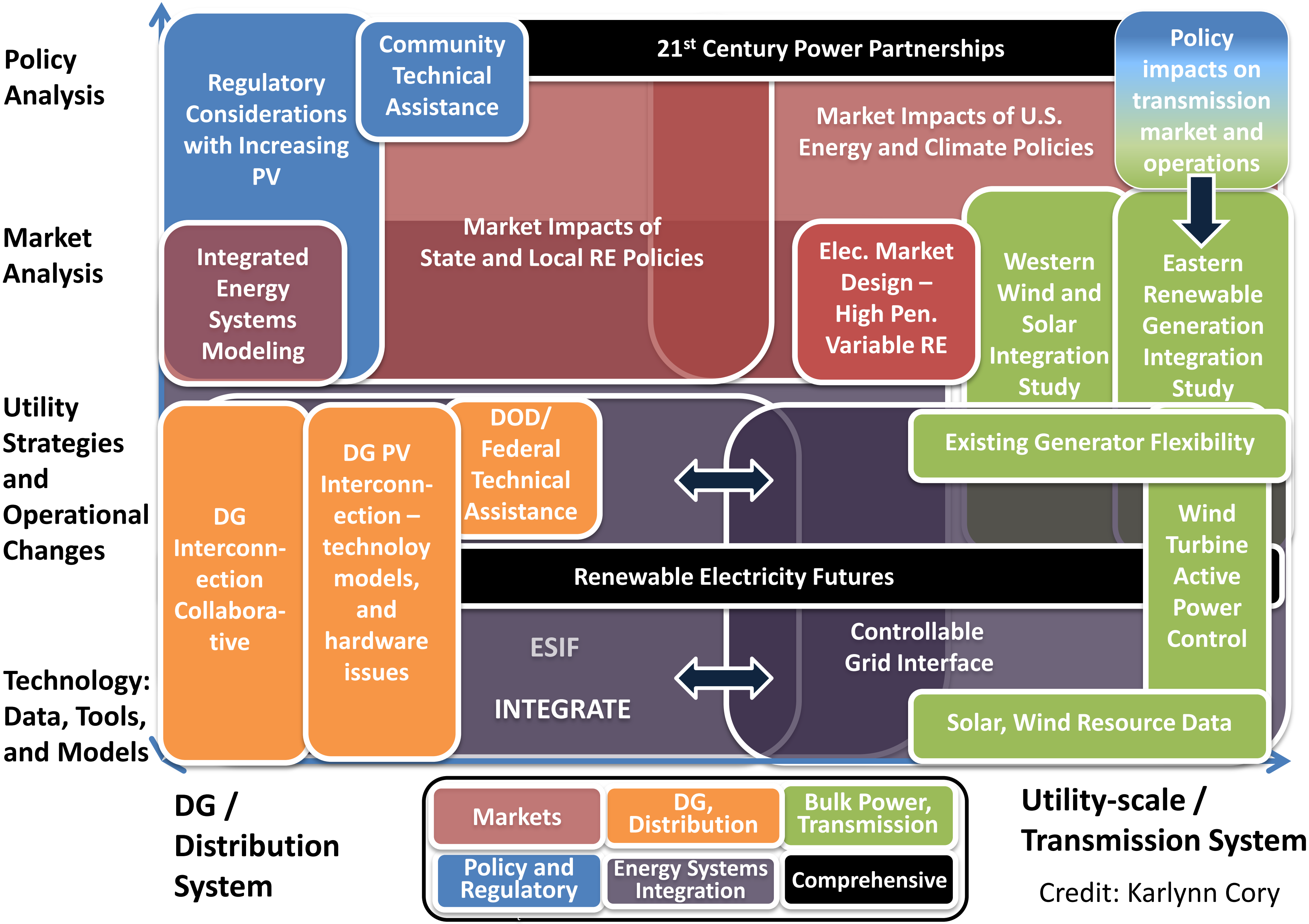


Source: Zinaman et al, NREL; http://www.nrel.gov/docs/fy15osti/62611.pdf

Conference Paper and PPT and *Electricity Journal* article

- **4th Annual Energy Policy Research Conference (EPRC) in San Francisco 9/4 – 9/5**
  - Future of the Electric Utility was one of 6 requested topics; our abstract was accepted
- **Title**: *Informing Electric Systems of the Future: Key Analysis Needs*
  - Publish results from utility interviews and utility/regulator meeting on analysis needs
  - Highlight NREL's ESI and Policy/Market analysis capabilities and results (in a supplement)
  - Identify priority, underserved analysis needs
- **Paper and Presentation**
  - Symposium issue of *The Electricity Journal* (Oct 31, 2014)
  - http://www.sciencedirect.com/science/article/pii/S1040619014002346

NREL Existing Analysis and Interactions



Credit: Karlynn Cory

1) Better Tools to Include Risk and Uncertainty in State Regulations and Competitive Market Rules

Overview: **Regulatory decisions tend to be driven by least-cost considerations; they may not adequately value key risks or uncertainty.**

Project Participant Insights:

1) **Incorporate societal goals beyond least-cost in institutional planning, regulatory priorities, utility decision making, and competitive market rules**
2) **Market rules encourage longevity and many generation owners excel at O&M. While beneficial to keeping costs down, operating older generator longer leaves little room for newer, more efficient technologies and can result in higher overall emissions.**

Analysis Possibilities:

1) **Quantify the costs and benefits of the least-cost status quo. Are better tools needed for identifying and managing risks?**
2) **Analyze alternatives to least-cost including lowest risk; examine regulatory best practices and challenges and competitive market rules through case studies**
3) **Review and refine competitive market rules, as well as IRP frameworks to more accurately value existing grid services and new technologies**
4) **Evaluate existing fleet and identify how much flexibility is possible (and at what cost) and how to measure the value of utility services in light of the changing market.**

2) Improve Clean Energy Cost and Benefit Valuation under Various Market Structures

Overview: Utility planning, ratemaking, and competitive electricity market rules may not adequately value all of the costs and benefits of the changing resource portfolio. Moreover, utility business models today may not be aligned with society's goals.

Project Participant Insights:

1) Regulated utilities could analyze more scenarios around today's risks/uncertainties
2) Utility capital priorities can be limiting: regulated utilities generally prefer to ratebase assets instead of signing a PPA (unless technology risk exists), and required expenses (e.g., environmental controls) limits capital available
3) General need for more information and analysis on valuation.

Analysis Possibilities:

1) Identify and communicate ways to accurately compare cost and performance of different technologies
2) Quantify the burden of rate cases – are they worth the expense?
3) Develop utility case studies of success, failure, and business evolution
4) Balance zero/negative load growth projections with existing operations
5) Convene a discussion of Future Utility Business Models to move the broader conversations forward.

3) Analyze Expectations and Implications of Increased Net Energy Metering and Distributed Generation (DG)

Overview: **The overall impact of net energy metering and DG are a growing concern in the electric sector for both utilities and regulators.**

Photo by Dennis Schroeder, NREL 04478

Project Participant Insights:

If realized, strong customer demand for DG could surprise many utilities and strain planning processes.

Analysis Possibilities:

1) **Identify and refine ways to incorporate the values and costs of DG into regulatory decisions, including rates, and explore sensitivities**
2) **Identify better technical and operational DG planning methods**
3) **Analyze utility business model options, particularly for higher-penetration DG, and explore the sensitivities and impacts.**

Photo by Ascension Technology, Inc., NREL 04478

4) Target Cost and Performance: Data Inputs and Technical Analysis

Overview: **Utilities and regulators want more information on clean energy technology cost and performance, and want to consider system adaptations to accommodate changing resource portfolios.**

Project Participant Insights:

1) **Low natural gas (NG) prices impact decisions because NG is the conventional generation technology of choice. Because NG fuel prices are so low, it costs less to run existing NG generation than build any new NG generation**
2) **Consider integrated analysis of grid functionality and generation supply because they interact closely and are hard to separate.**

Analysis Possibilities:

1) **Identify analysis methods that accommodate changing resource portfolios**
2) **Identify optimal grid functions, explore comprehensive cost and benefit valuation options, and evaluate ways to include valuation in price signals and markets**
3) **Analyze system operational flexibility best suited to support new technologies.**