The Renewable Energy Revolution and the Quadrennial Energy Review

Karen G. Wayland

7th Annual Nebraska Wind and Solar Conference

October 29, 2014

Fundamental Changes in the U.S. Energy Sector

Increasing Energy Production

- Natural gas production
- growth Oil production growth
- Intermittent renewables
- Distributed generation/ energy resources
- Increased generation/production/demand efficiency

Policy Developments

- CAFÉ
- 111 (d)
- Clean Air Act
- RFS
- RPS (state)
- RGGI (regional)

Technology Advances

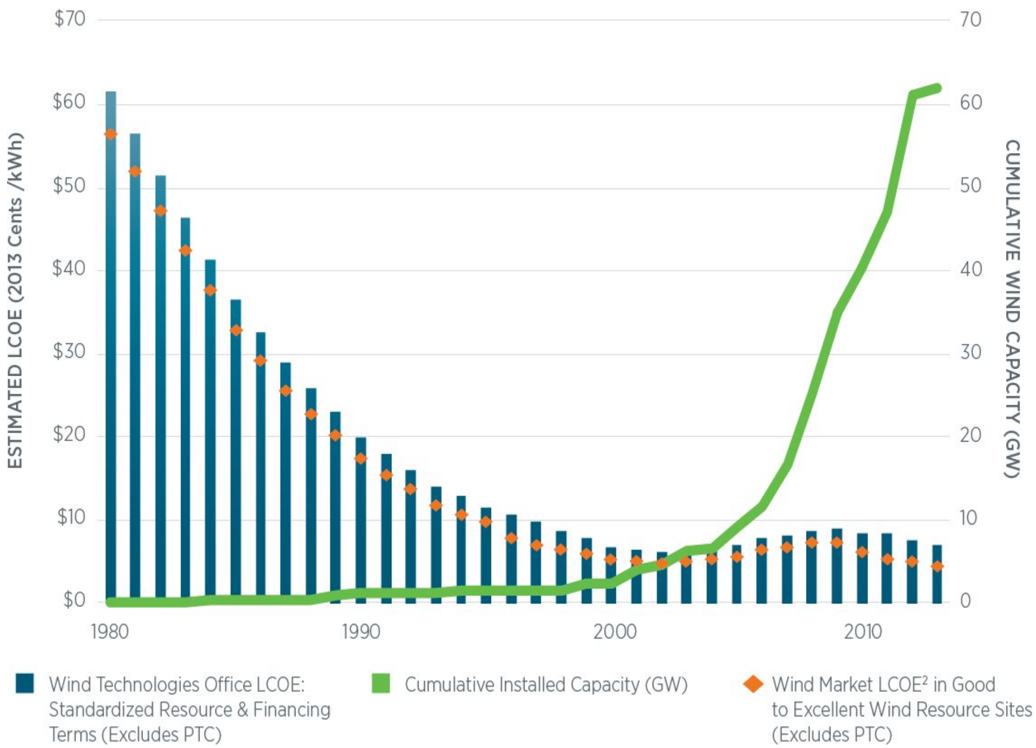
- Solar (central and rooftop)
- Wind
- Demand-side
- Hydraulic fracturing

Energy Security Changes

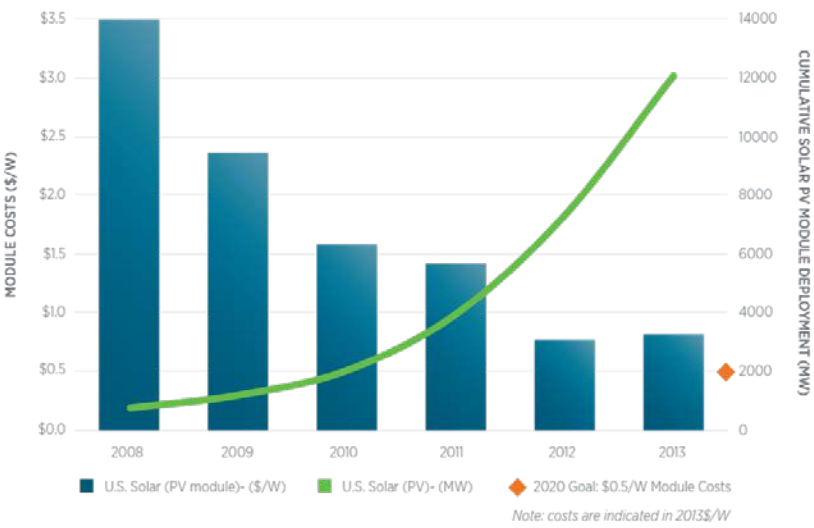
- Decreased N. American energy imports
- Climate change impacts
- Vulnerabilities more evident, including aging infrastructures, physical and cyber threats
- Increased interdependencies
- Increased energy support required by allies

Revolution Now:
Transformational Technologies

U.S. Deployment & Cost for Land-Based Wind 1980-2013

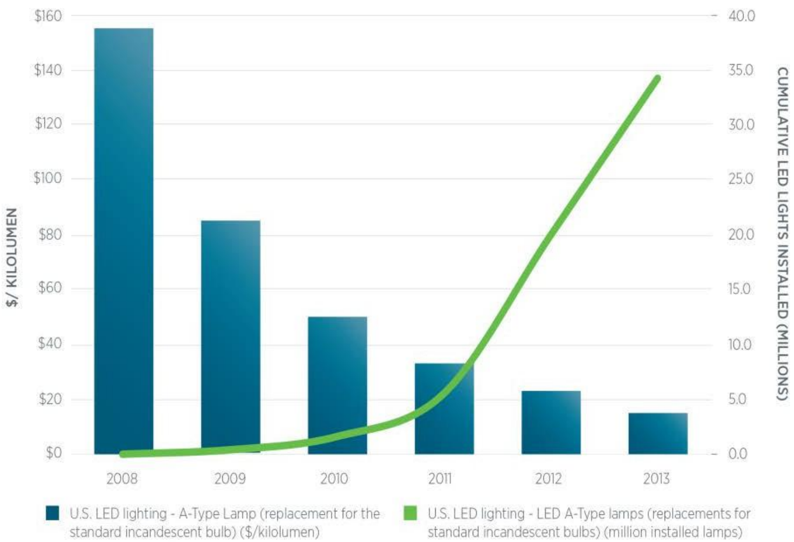


U.S. Deployment and Cost for Solar PV Modules 2008-2013

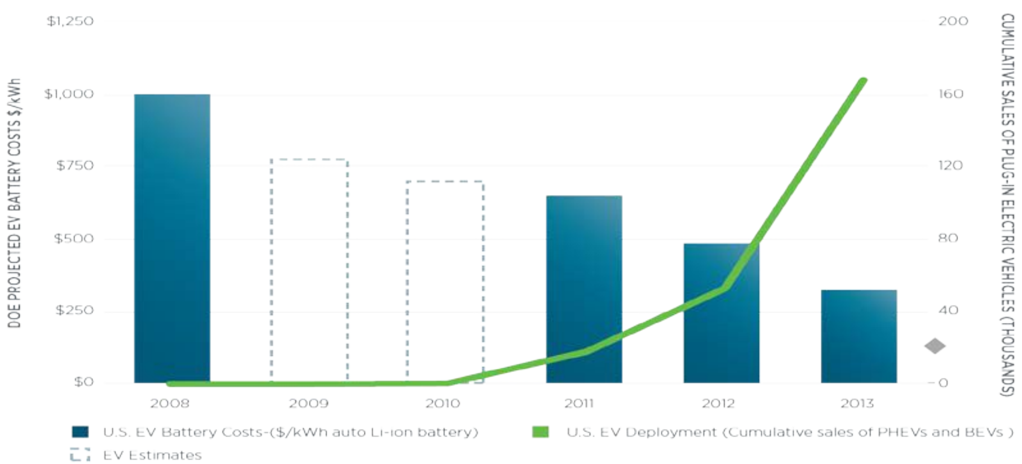


Revolution Now: Transformational Technologies

U.S. Deployment and Cost for A-Type LED Lights 2008-2013

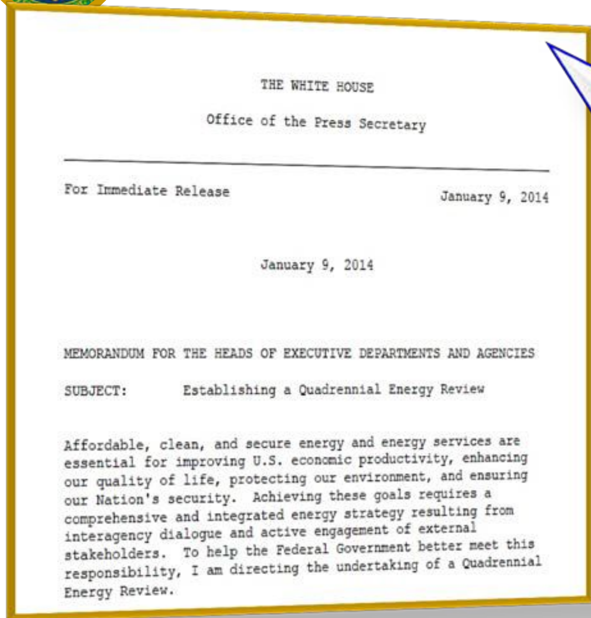


U.S. Deployment and Cost for Electric Vehicles and Batteries 2008-2013



The Quadrennial Energy Review

PM on the Quadrennial Energy Review


THE WHITE HOUSE

Office of the Press Secretary

For Immediate Release January 9, 2014

January 9, 2014

MEMORANDUM FOR THE HEADS OF EXECUTIVE DEPARTMENTS AND AGENCIES

SUBJECT: Establishing a Quadrennial Energy Review

Affordable, clean, and secure energy and energy services are essential for improving U.S. economic productivity, enhancing our quality of life, protecting our environment, and ensuring our Nation's security. Achieving these goals requires a comprehensive and integrated energy strategy resulting from interagency dialogue and active engagement of external stakeholders. To help the Federal Government better meet this responsibility, I am directing the undertaking of a Quadrennial Energy Review.

"Affordable, clean, and secure energy and energy services are essential for improving U.S. economic productivity, enhancing our quality of life, protecting our environment, and ensuring our Nation's security.

Achieving these goals requires a comprehensive and integrated energy strategy resulting from interagency dialogue and active engagement of external stakeholders.

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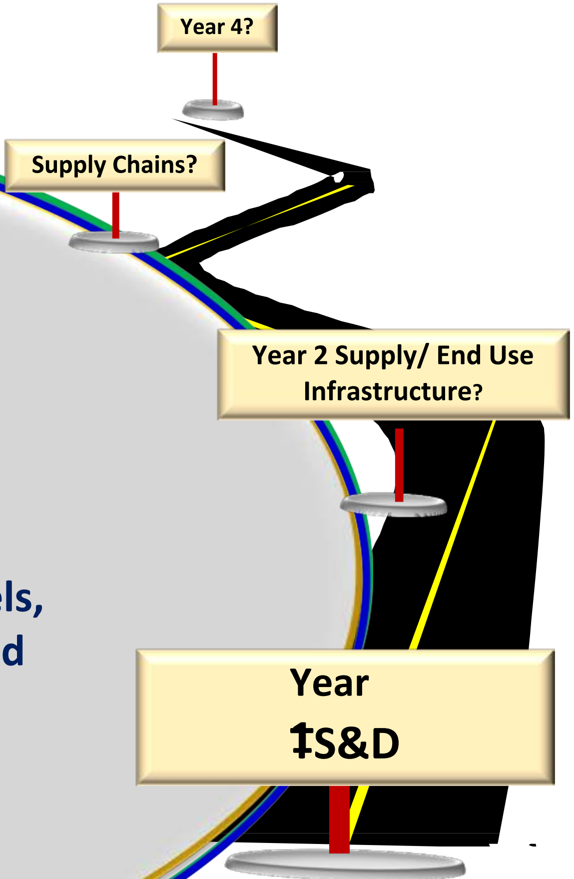
President Barack Obama
January 9, 2014

- **Integrated view** of short-, intermediate-, long-term objectives for Federal energy policy;
- **Outline of legislative** proposals to Congress;
- **Executive actions** (programmatic, regulatory, fiscal, etc.) across multiple agencies;
- **Resource requirements** for RD&D and incentive programs; and
- **Strong analytical base** for decision-making.
- **First year focus** on TS&D infrastructure including: electricity transmission and distribution systems, liquid and gas pipelines, export infrastructure; interdependencies; climate and environment.

QER is a 4 year Roadmap:

Year One Will Focus on TS&D Infrastructure



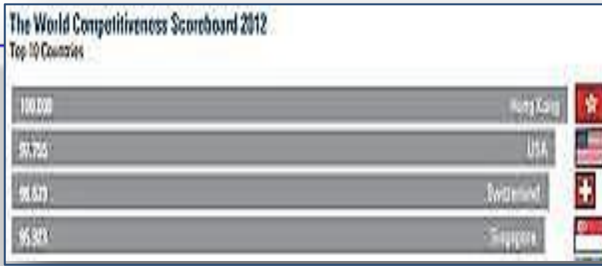
TRANSMISSION, STORAGE &DISTRIBUTION

- The initial QER exercise will focus on TS&D -- infrastructure that links energy supplies, carriers, or by-products to intermediate and end users, or waste disposal sites

- TS&D networks help deliver electricity, transportation fuels, and heat to industry and 300 million consumers every day and provide feedstocks for a large range of products

- These infrastructures tend to set supply and end use patterns, policies, investments and practices in place for decades

National Energy Goals



Economic Competitiveness: Energy infrastructure should enable the nation to, under a level playing field and fair and transparent market conditions, produce goods and services which meet the test of international markets while simultaneously maintaining and expanding jobs and the real incomes of the American people over the longer term. Energy infrastructures should enable new architectures to stimulate energy efficiency, new economic transaction, and new consumer services.

Environmental Responsibility: Energy infrastructure systems should take into consideration a full accounting (on a life-cycle basis) of environmental costs and benefits in order to minimize their environmental footprint.

Energy Security: Energy Infrastructure should be minimally vulnerable to the majority of disruptions in supply and mitigate impacts, including economic impacts, of disruptions by recovering quickly or with use of reserve stocks. Energy security should support overall national security.

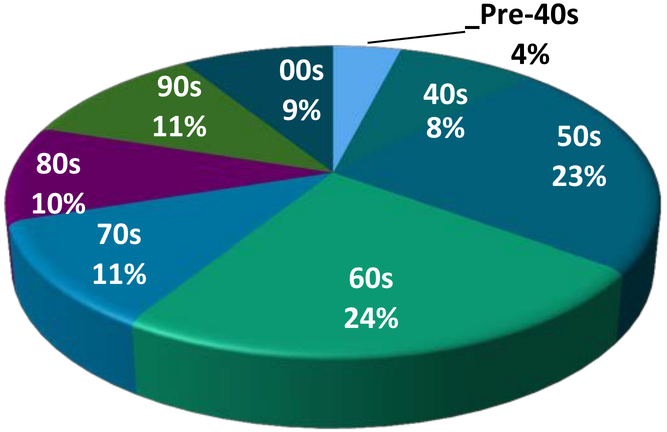
Limitations of Current System

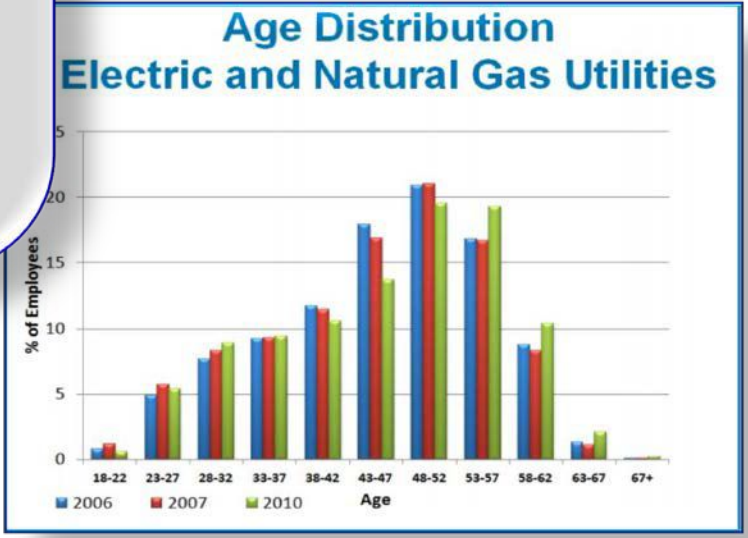
Age: Over 50% of the nation's gas transmission and gathering pipelines were constructed in the 1940s, 1950's and 1960's

Cost: EEI estimates that by 2030, we will need to at total investment of $1.5 trillion to $2.0 trillion by the electric utility industry. Natural gas infrastructure investment needed: $19.2 billion/ yr. by 2030.

Workforce: over 60% of the workers in areas like electric and gas utilities are likely to retire or leave the industry within a decade

Age by decade of gas gathering/ transmission lines





Age Distribution of Gas/Electric Utility Employees

Short and Long-Term Vulnerabilities Are Growing

Climate Change: Weather-related power outages have increased from 5-20 each year in the mid-1990s to 50-100 per year in the last five years.

Cyber-Security: 53% of all cyber-attacks from October 2012 to May 2013 were on energy installations.

Physical Threats: There were three highly visible attacks on grid infrastructure in 2013. Supply chains for key components of grid infrastructure are not robust.

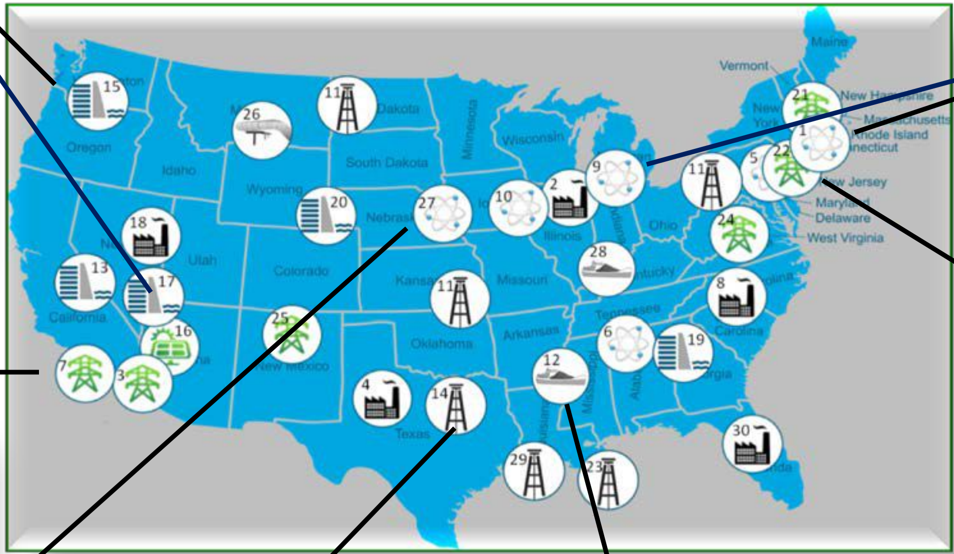
Supply/Demand Shifts: The lack of pipeline infrastructures for associated gas in the Bakken has resulted in large-scale flaring of this gas, in amount sufficient to be seen from space.

Interdependencies: The interdependencies of the electric and fuel infrastructures seen in Superstorm Sandy greatly complicated the response and recovery.

Recent Events Illustrate U.S. Energy Sector Vulnerability to Climatic Conditions

Lower water levels: Reduced hydropower

Wildfires: Damaged transmission lines



Cooling water intake or discharge too hot: Shutdown and reduced generation from power plants

Intense storms: Disrupted power

Flooding: Impacts on inland power plants

Water restrictions due to drought: Limiting shale gas and power production

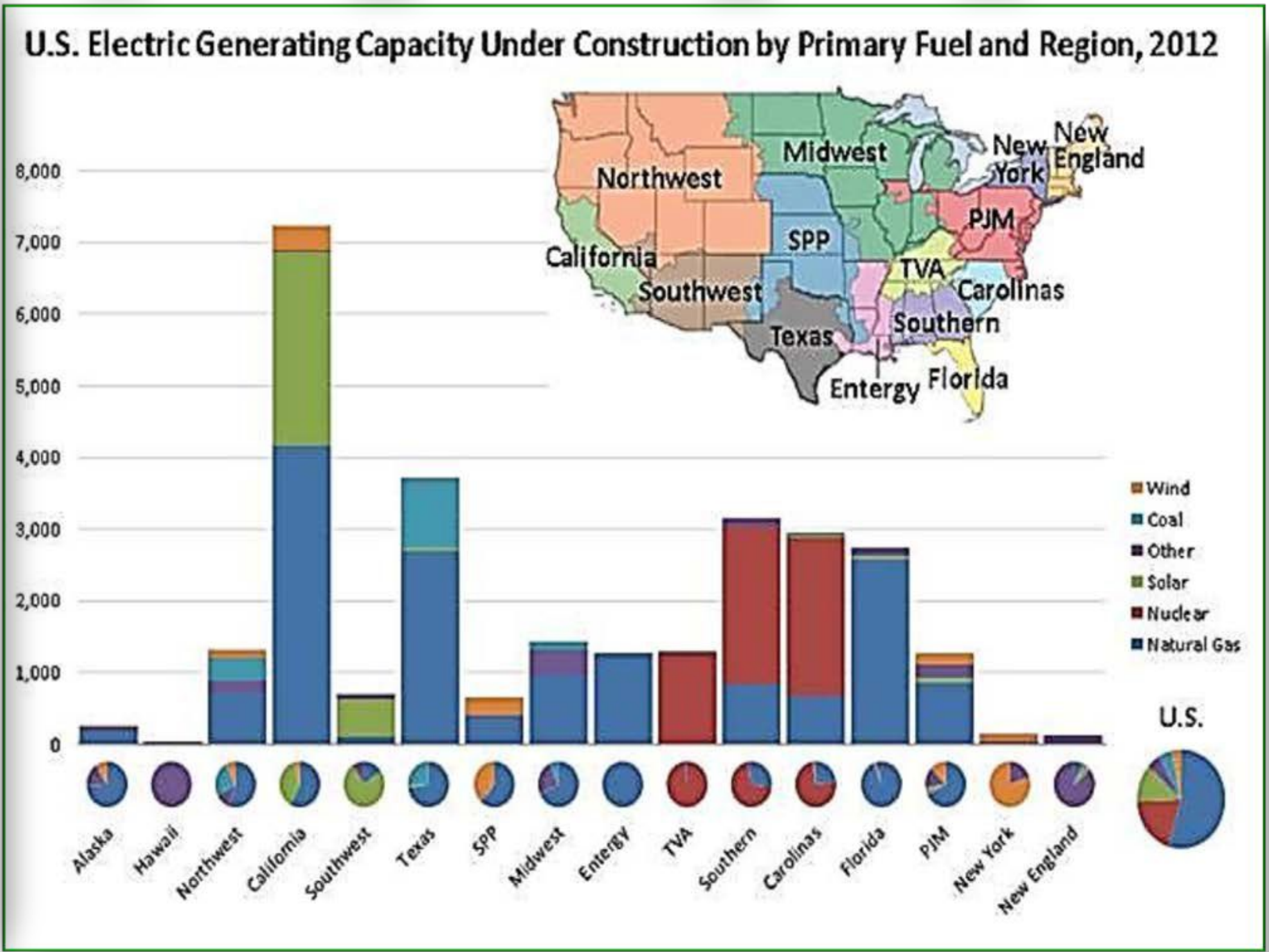
Lower river levels: Restricted barge transportation of coal and petroleum products

Regional Nature of U.S. Energy Profile

Regional Differences in New Generation Capacity

- In 2012, natural gas was the most common fuel source for expanding generation capacity under construction.
- Southwestern states saw the majority of solar expansion, while wind development occurred in SPP/Midwest/NY/Northeast.
- Recent nuclear developments have occurred exclusively in the Southeast.
- The average new generation unit size was much larger in Southeast than in other regions of the country.

solar natural gas wind nuclear

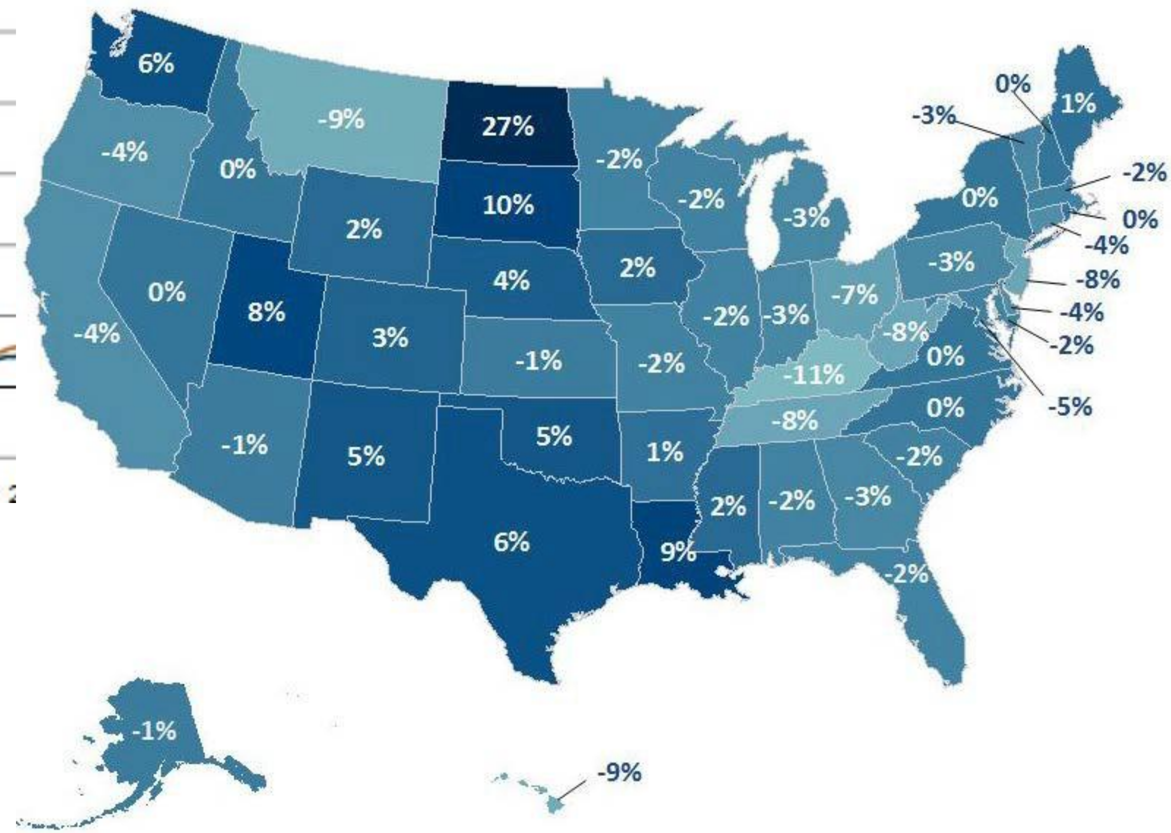


Sources: EEI, *Historical Statistics of the Electric Utility Industry*, EIA *Electric Power Annual*, Consumer price index, Bureau of Labor Statistics.

Changing Energy Demand Profiles

Electricity demand growth   1950-2040

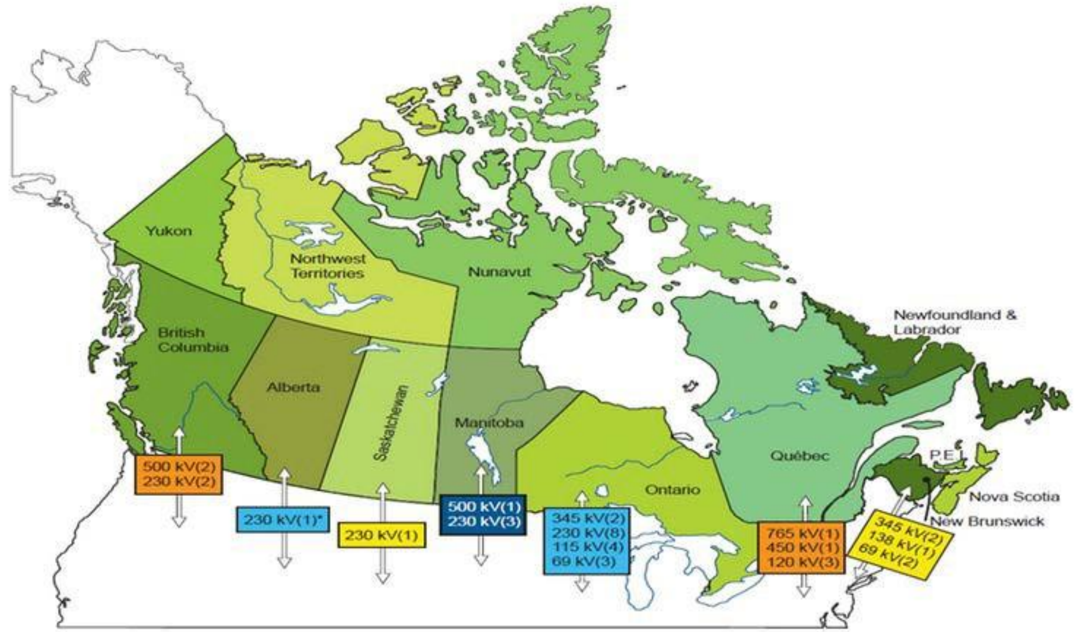
Percent Change in Retail Sales (kWh),

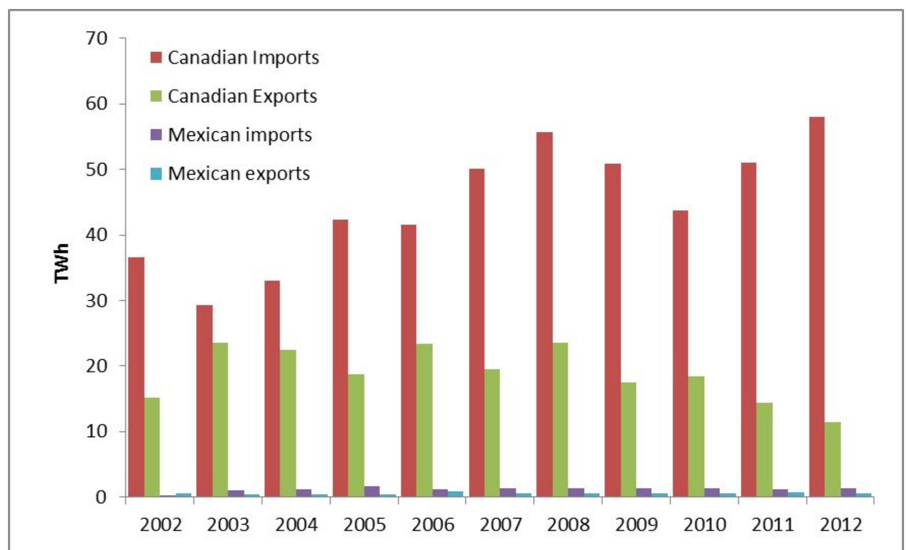


Source: EIA Annual Energy Outlook 2014.

Electricity Trade in North America

- Imports from Canada have increased over the past decade, while exports have decreased.
- There are proposals for Canadian suppliers to provide balancing services to New England and the Midwest to support the addition of renewable generation.
- Electricity trade with Mexico, on the other hand, has been quite modest.





Source: EIA, CEA

QER Process

QER Process: One-Year Plan

Phase 1: Preliminary Work

2 months

Phase 2: Infrastructure Analysis and Engagement

6 months

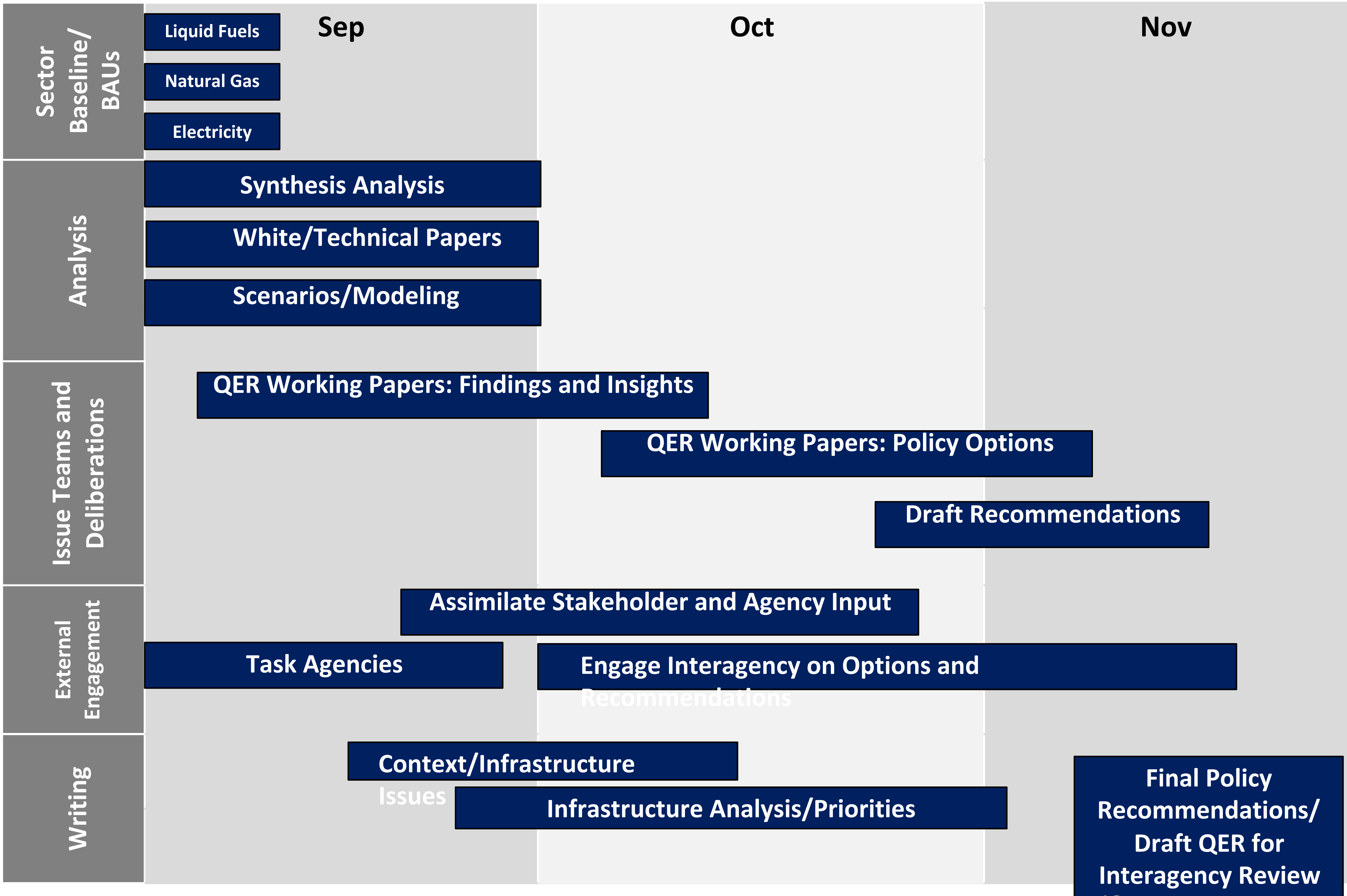
Phase 3: Policy Analysis and Engagement

6 months

Phase 4: Approval Process

2 months

QER 1 Schedule – Sep – Nov 2014



QER Electricity/Interdependency Analyses

	Working Papers	Detailed analyses of …
ELECTRICITY	**E1: GHG reductions and other drivers of grid changes**	• Degree to which the grid can adapt to changing generation portfolios that support GHG reductions while maintaining reliability and affordability • Grid implications of significant increases in end use efficiency and large scale penetration of distributed generation
	E2: Grid reliability and resiliency	• System vulnerabilities to climate change, extreme weather, cyber and physical attacks • Appropriate levels of reliability/resilience, role of smart grid, other technical options
	E3: Evolution of the distribution system	• Impact of distributed energy technologies, smart grid, and other potentially disruptive capabilities • Types of challenges these and other issues represent for the utility business model and regulators
	E4: Flexibility	• Degree of flexibility needed to integrate renewables into the grid • How storage and other capabilities can improve grid operation • Identification of barriers to planning, siting or cost allocation for new electric transmission lines, including costs of delay
INTERDEPENDENCY	**I1: Gas-Electric Interdependency**	• Infrastructure implications for gas-electricity coordination • Impact of intermittent renewable source on NG demand
	I2: Disruptions of interdependent energy infrastructures	• Disruptive events specific interdependencies, including gasoline-elec, LF – Elec, NG – Elec, and LF – NG connections
	I3: Energy transport infra. interdependencies & environ.	• Implications of increased crude oil transport by rail and barge • Impact on other energy commodities and infrastructures, as well as other commodities
ENVIRON.	**C1: Conventional air pollution from stationary TS&D sources**	• Emissions of Hazardous Air Pollutants and ozone precursors from petroleum refineries, biofuel refineries, and natural gas compressor stations. • Cost-benefit of additional efficiency opportunities
	C2: Land use and siting	• Role of Federal Government in siting TS&D infrastructure

Interagency Consultation, Stakeholder Engagement

Agency Stakeholders

Agriculture
Defense
Commerce
EPA
HHS
Homeland Security
HUD
Interior
Labor
State
Transportation
Treasury
Veterans Affairs
White House, other

DOE Stakeholders

National Labs
SEAB/PCAST

QER

Co-chaired by DPC, OSTP

Energy/Science Programs

External Stakeholders

Congress
Industry
NGOs
State, local and tribes
Financial Community
Academia
Public
Other North American Countries

Public Stakeholder Meetings
www.energy.gov/qer

	Location	Date	Chair
Vulnerabilities (Cyber, Physical, Climate, Interdependencies)	Washington, DC	4/11	Moniz
Infrastructure Constraints—New England	Topic	4/21	Moniz
Petroleum Product TS&D	New Orleans, LA	5/27	Moniz
Water-Energy Nexus	San Francisco, CA	6/19	Holdren
Electricity TS&D—West	Portland, OR	7/11	Poneman
Natural Gas TS&D	Pittsburgh, PA	7/21	Moniz
Gas-Electricity Interdependence	Denver, CO	7/28	Utech
Infrastructure Constraints—Bakken	Bismarck, ND	8/8	Moniz, Foxx, Holdren, Schneider
Rail, Barge, Truck Transportation	Chicago, IL	8/8	Moniz, Foxx, Holdren, Darcy
State, Local and Tribal Issues	Santa Fe, NM	8/11	Moniz, Jewell
Infrastructure Siting	Cheyenne, WY	8/21	Moniz, Schneider
Electricity TS&D - East	Newark, NJ	9/8	Moniz
Finance and Market Incentives	New York, NY	10/6	Moniz

- **Briefing memo**
- **Agenda and speakers**
- **Statements**
- **Meeting summary**
- **Meeting transcript**

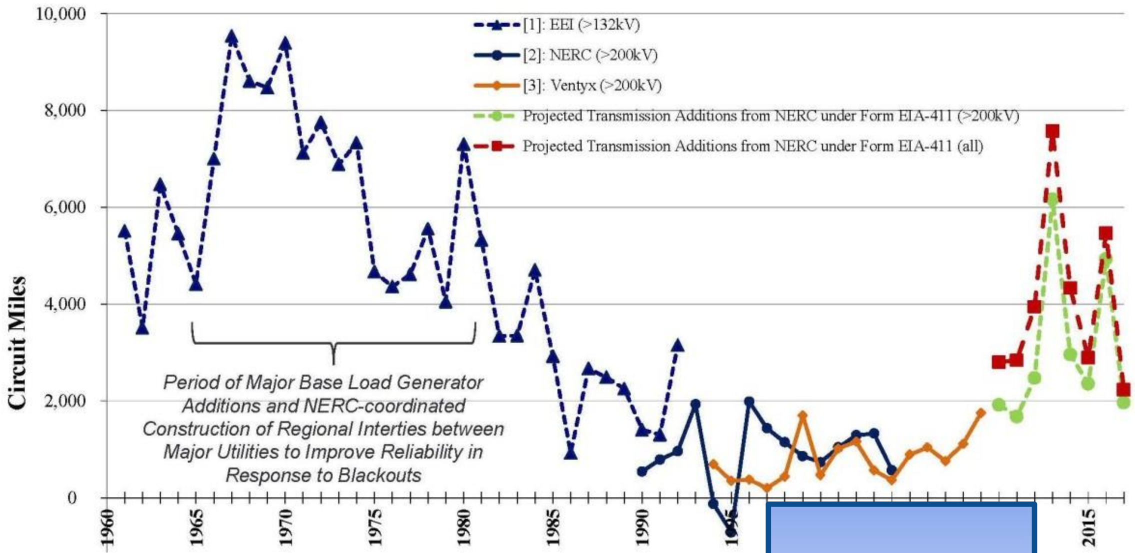
Categories of Comments

- Industry Insights
- Recommendations

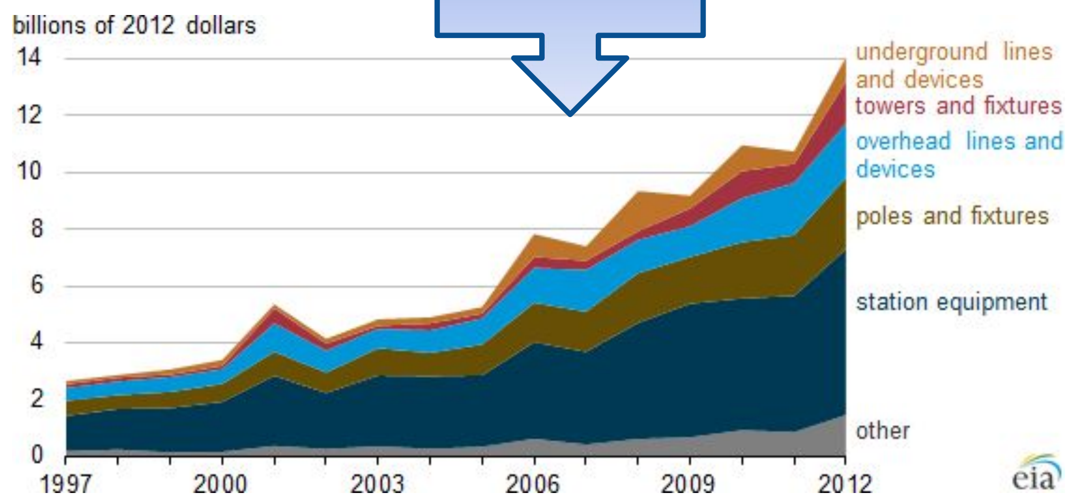
1) **How to operate the system safely, fairly, efficiently**
2) **Who should be responsible for reliability, security, safety, flexibility (enforcement, new investment, standards, etc)**
3) **How to allocate costs of resilience measures**

Insights for the Renewables Revolution on Transmission, Storage and Distribution

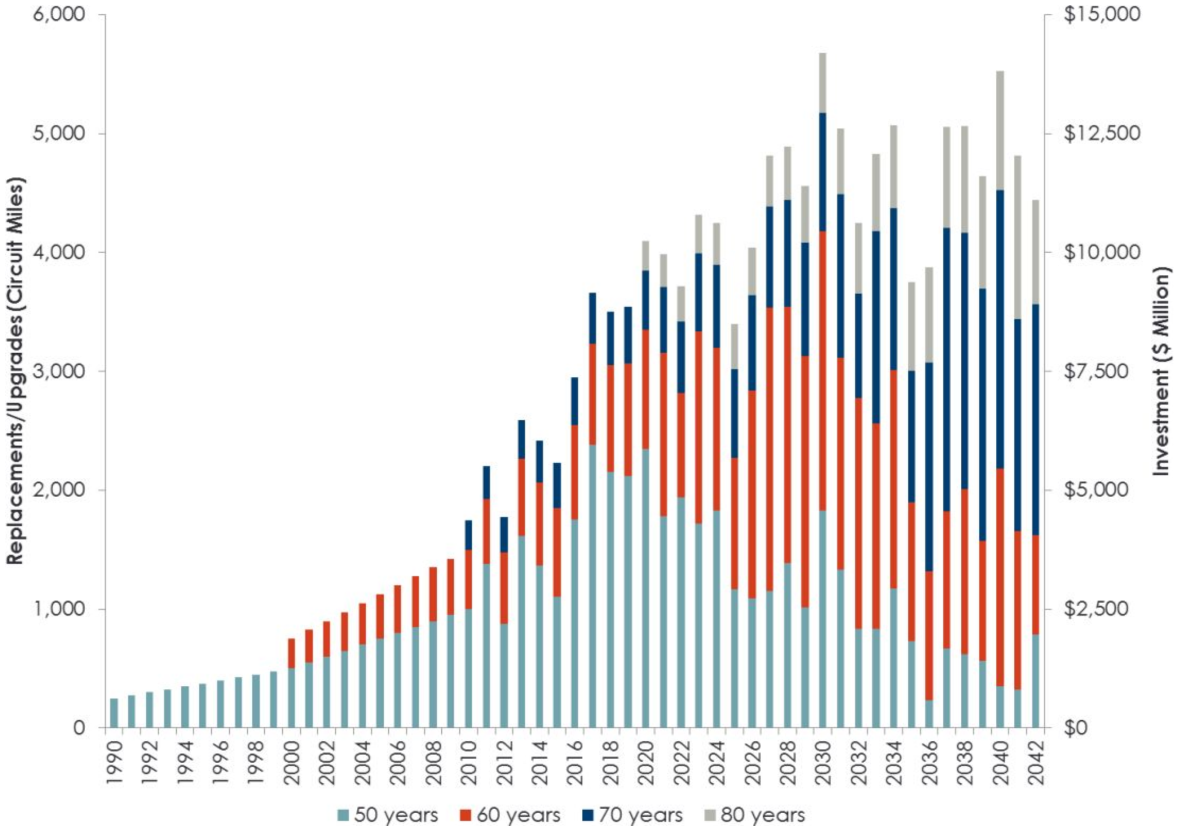
Historic and Projected Expansion of Transmission Circuit Miles



1997–2012 Annual Investment in Transmission Infrastructure by Investor- Owned Utilities

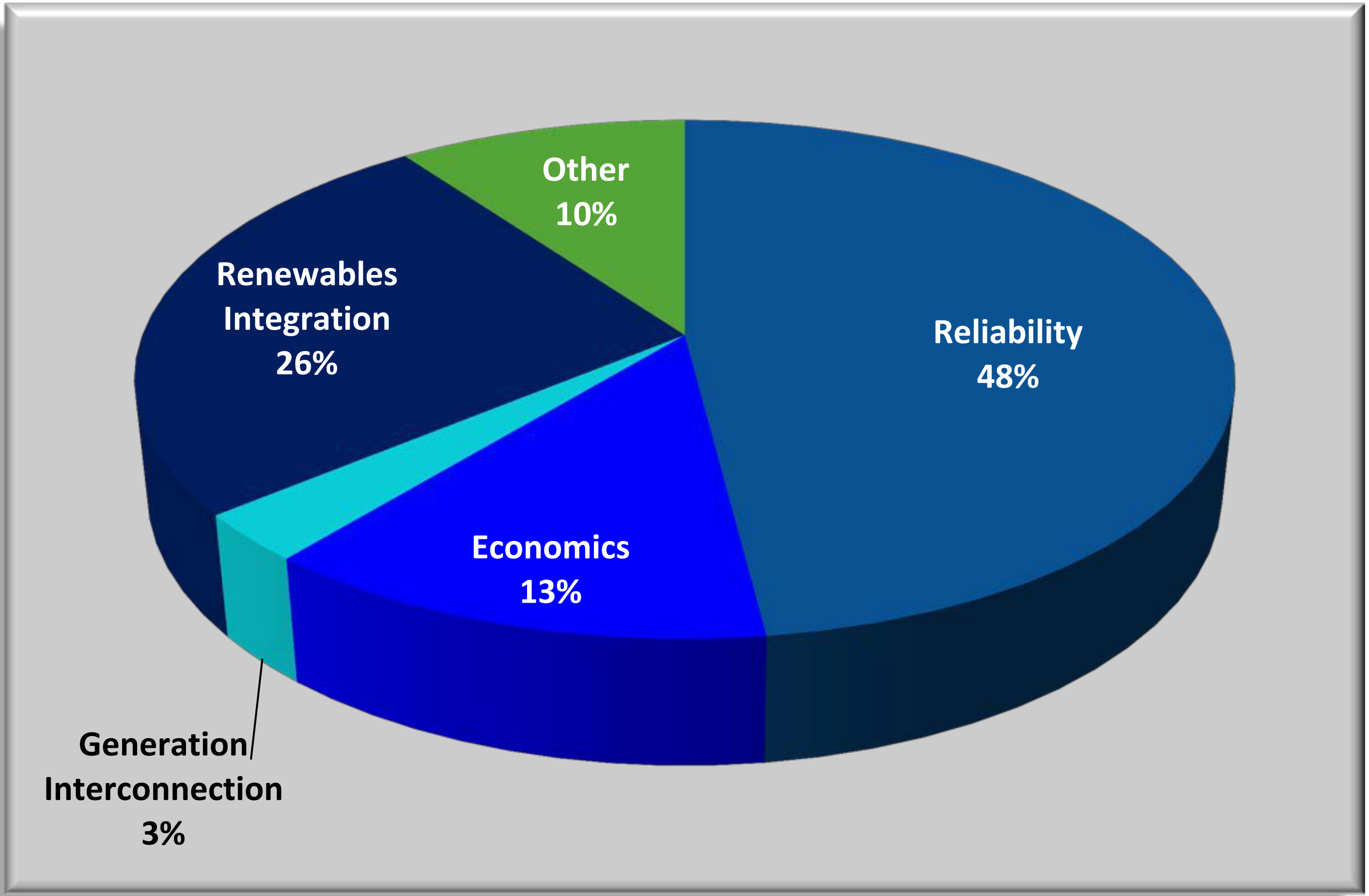


Projected Circuit Miles to be Replaced/ Upgraded and Total Required Investment



Sources and notes: From Brattle Electricity Baseline. Circuit miles of overhead electric lines from EEI's Historical Statistical Yearbook. Data excludes REA cooperatives. Analysis assumes that 25% of all facilities will need to be replaced after 50, 60, 70, and 80 years in service. The bars correspond to both axis based on the assumption that each circuit mile replaced/upgraded will cost on average $2.5 million per mile.

Transmission Investment: Drivers



Reported Drivers of Projected Circuit-Miles of Transmission Addition

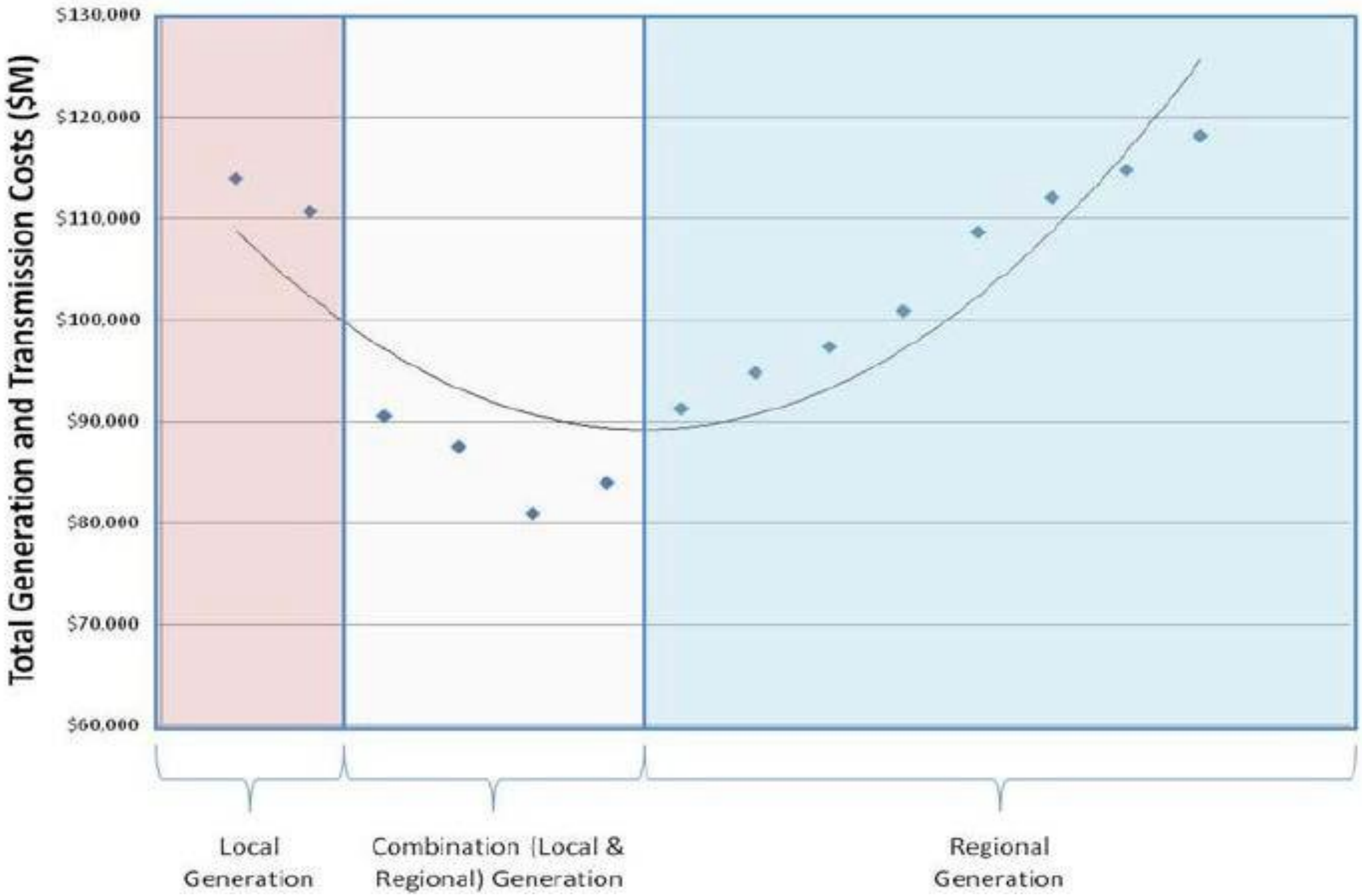
(2011-2015 as reported voluntarily to NERC and in EIA form 411 by IOUs, coops-munis, state/federal power agencies, ISOs/RTOs, and merchant developers)

Regional Variations in Transmission Constraints

Region	Findings
Western Interconnection	- Many paths heavily utilized but do not appear to act as reliability-threatening constraints - More congestion expected due to new development of renewable resources and generator retirements - San Onofre Nuclear Generating Station closure created local reliability challenges
Midwest (MISO North, SPP, western PJM, non-RTO areas)	- Congestion results from transmitting high and growing levels of wind generation from western sources to distant loads - Differences in generation capacity reserve margins, which are higher in the west and central regions, increase west-to-east flows which creates congestion
Northeast (NYISO, ISO-NE, eastern PJM)	- Constraints have impacted flows for fewer hours in recent years - Congestion lower due to generation and transmission additions combined with lower demand - Congestion persists in central New York, New York City, and Long Island areas - Increasing congestion due to west-to-east flows of off-peak generation from remote wind locations
Southeast (Non-RTO areas in NC, SC, TN, AR, GA, AL, MS, LA, FL, parts of TX)	- No reports of persistent transmission constraints

Connecting to Renewables

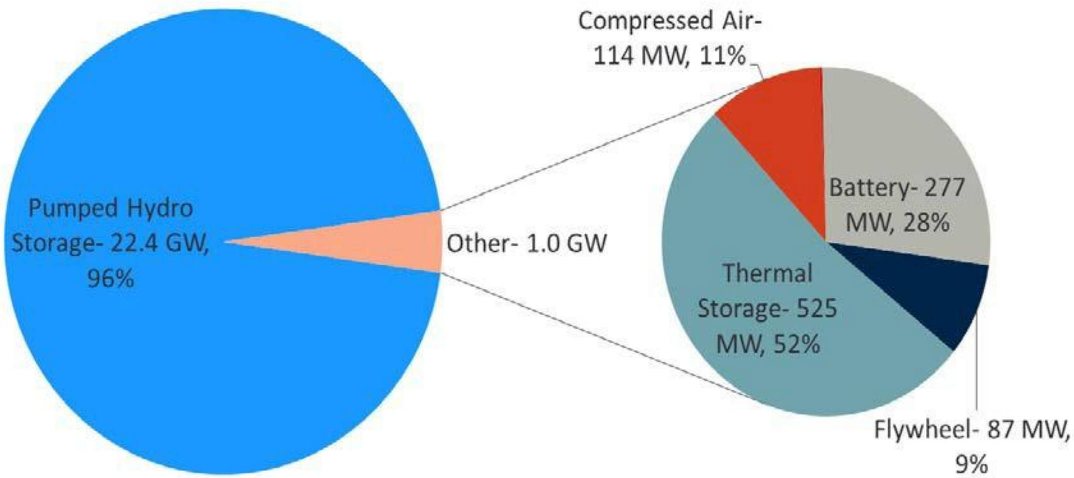
MISO Analysis of Total Renewable Generation and Transmission Costs



Source: MVP Report.

Game Changer: Storage

Existing Storage Installations by Rated Power



Technology Type	Total Installations	Total Capacity MW	Average Size MW
Pumped Hydro	39	22,395	574
Thermal Storage	105	525	5
Electrochemical	151	279	2
Compressed Air	3	114	38
Flywheel	26	87	3
All	**324**	**23,399**	**72**

Energy Storage Capacity under Development

	Under Construction			Announced/Contracted		
Technology Type	**Total Installations**	**Total Capacity** *MW*	**Average Size** *MW*	**Total Installations**	**Total Capacity** *MW*	**Average Size** *MW*
Pumped Hydro	0	0.0	0.0	5	3,950.0	790.0
Compressed Air	1	0.1	0.1	3	626.0	208.7
Electrochemical	57	24.0	0.4	26	72.6	2.8
Flywheel	0	0.0	0.0	4	10.2	2.5
Thermal Storage	2	260.0	130.0	1	6.0	6.0
All	**60**	**284.0**	**130.5**	**39**	**4,664.8**	**1,010.0**

Source: DOE, Global energy storage database

Valuing the Benefits of Storage

Services	Service Description	Response Speed
Voltage control	The injection or absorption of reactive power to maintain transmission-system voltages within required ranges	Seconds
Regulation	Power sources online, on automatic generation control, that can respond rapidly to system-operator requests for up and down movements; used to track the minute-to minute fluctuations in system load and to correct for unintended fluctuations in generator output	~ 1 min
Spinning reserve	Power sources online, synchronized to the grid, that can increase output immediately in response to a major generator or transmission outage	Seconds to 10 min
Supplemental reserve	Same as spinning reserve, but need not respond immediately; units can be offline but still must be capable of reaching full output within the required 10 min	< 10 min
Replacement reserve	Same as supplemental reserve, but with a 30-min response time; used to restore spinning and supplemental reserves to their pre-contingency status	< 30 min

Source: Adapted from Frequency Regulation Basics and Trends (ORNL/TM-2004/291)

California Storage Mandate

- 1325 megawatts by 2020

Proposed Energy Storage Procurement Targets (in MW)[22]

Storage Grid Domain Point of Interconnection	2014	2016	2018	2020	Total
Southern California Edison					
Transmission	50	65	85	110	310
Distribution	30	40	50	65	185
Customer	10	15	25	35	85
Subtotal SCE	90	120	160	210	580
Pacific Gas and Electric					
Transmission	50	65	85	110	310
Distribution	30	40	50	65	185
Customer	10	15	25	35	85
Subtotal PG&E	90	120	160	210	580
San Diego Gas & Electric					
Transmission	10	15	22	33	80
Distribution	7	10	15	23	55
Customer	3	5	8	14	30
Subtotal SDG&E	20	30	45	70	165
Total - all 3 utilities	200	270	365	490	1,325

Some Key Findings

- Long distance electricity transmission additions appear to be adequate to meet demand; key issue is how electricity business models impede or aid integration of renewable resources into electricity mix via distributed generation vs. centralized power stations/long distance transmission
- Timing of transmission siting and permitting process mismatched to renewables development
- Energy data/information development/harmonization
- Interdependence of many infrastructures on electricity is growing problem

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