QUADRENNIAL ENERGY REVIEW

ENERGY TRANSMISSION, STORAGE, AND DISTRIBUTION INFRASTRUCTURE

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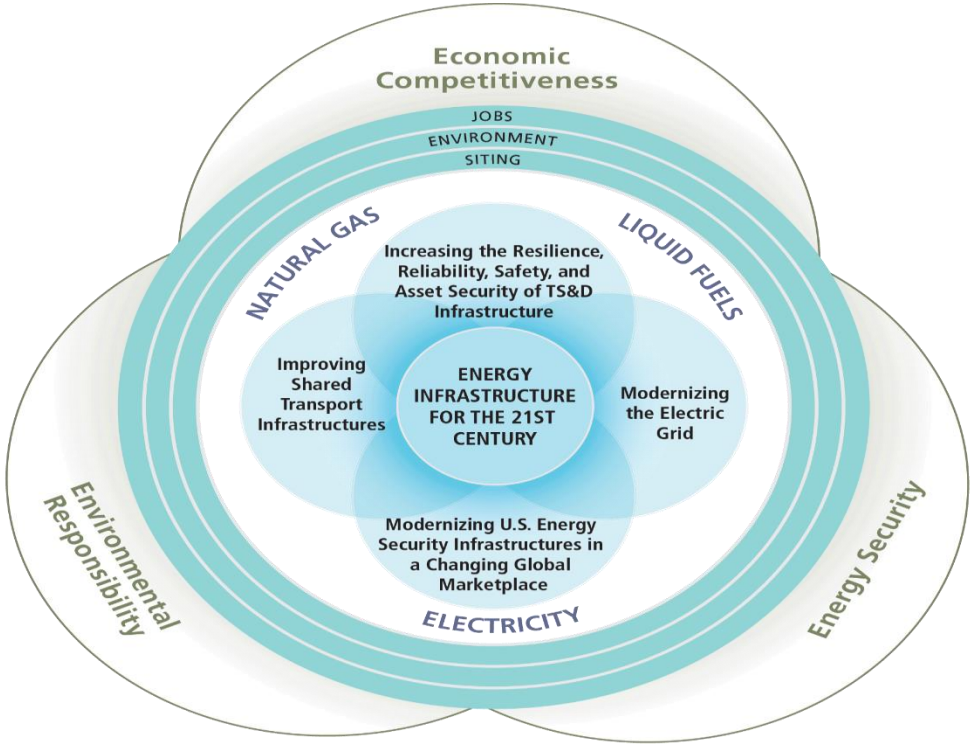
An Unconventional Look at Energy Systems

- The United States has one of the most advanced energy systems in the world
- The energy transmission, storage, and distribution (TS&D) infrastructure is increasingly complex and interdependent
- It must handle demanding system requirements (e.g., 24/365, on-demand, highly-reliable energy)
- The longevity and high capital costs mean that TS&D infrastructure decisions today will affect the national energy system for decades to come

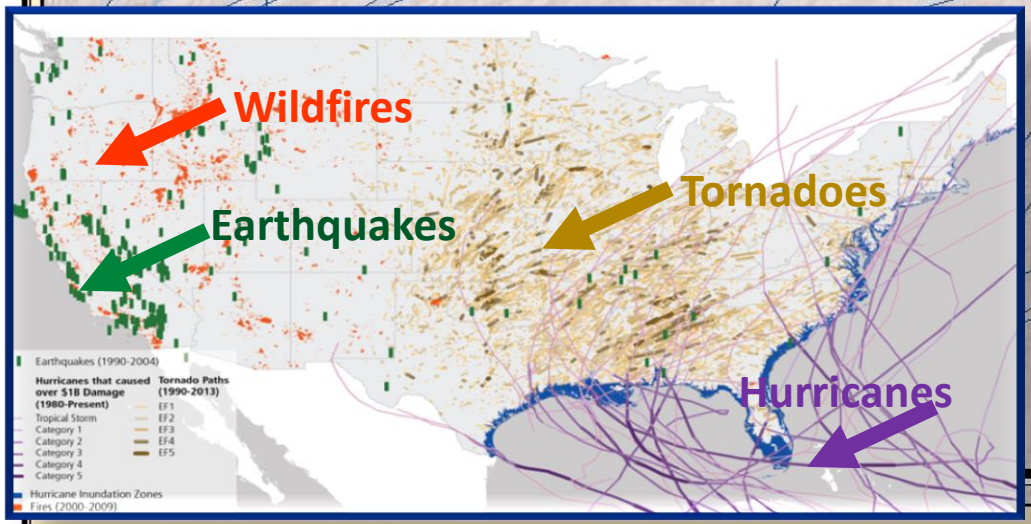


INCREASING THE RESILIENCE, RELIABILITY, SAFETY, AND ASSET SECURITY OF TS&D INFRASTRUCTURE

Recorded Tornado Paths

Cushing, OK Facility

Illustrations of Tornado and Hurricane Tracks, Wildfires, Earthquakes, and Coastal Inundation

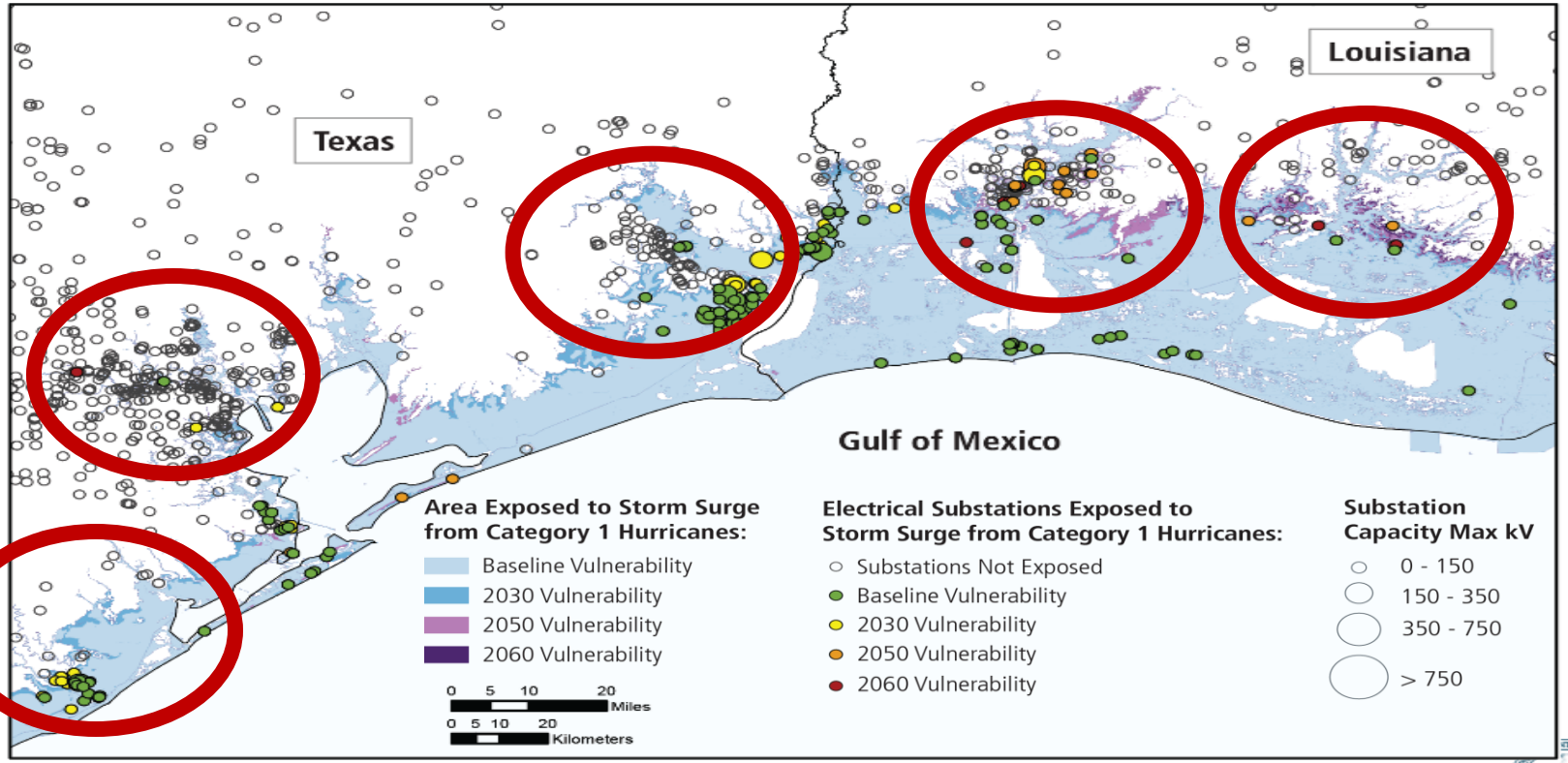


9 13.5 18 Miles

Tornado Paths
Cushing, OK

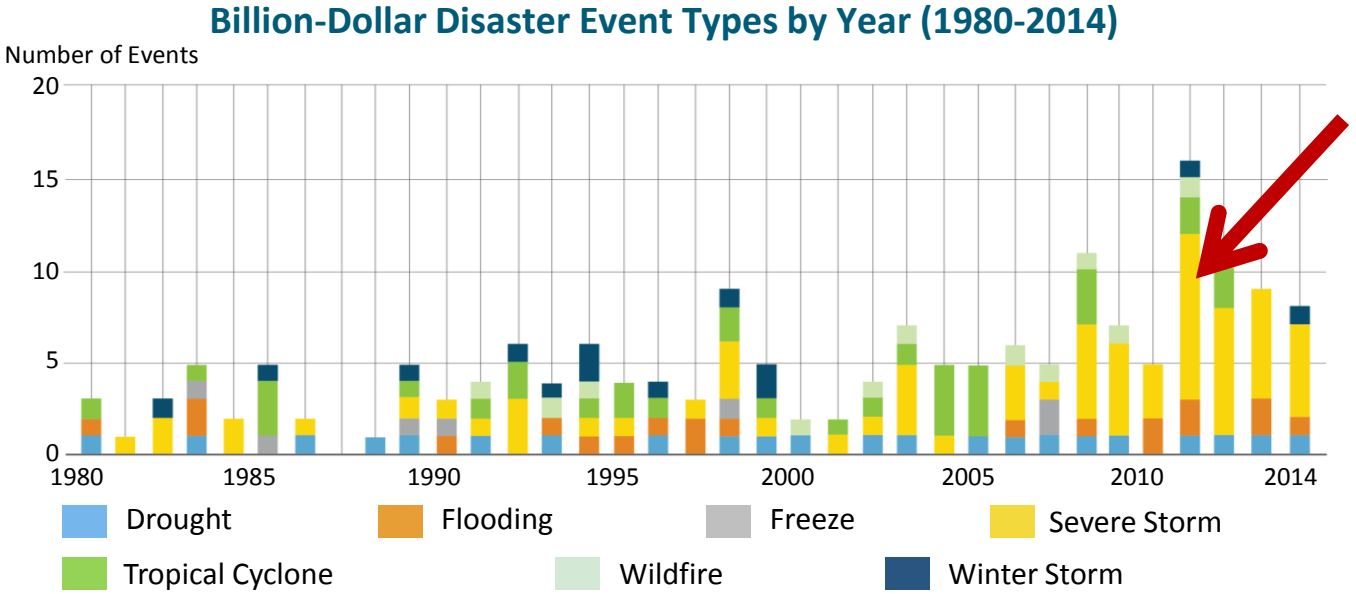
Vulnerabilities and Disruptions

Disruptions of TS&D infrastructures have serious consequences for the Nation and many regions of the country. Extreme weather and climate change is a leading environmental risk to this infrastructure.



Gulf Coast Electricity Substation Facilities' Exposure to Storm Surge under Different Sea-Level Rise Scenarios

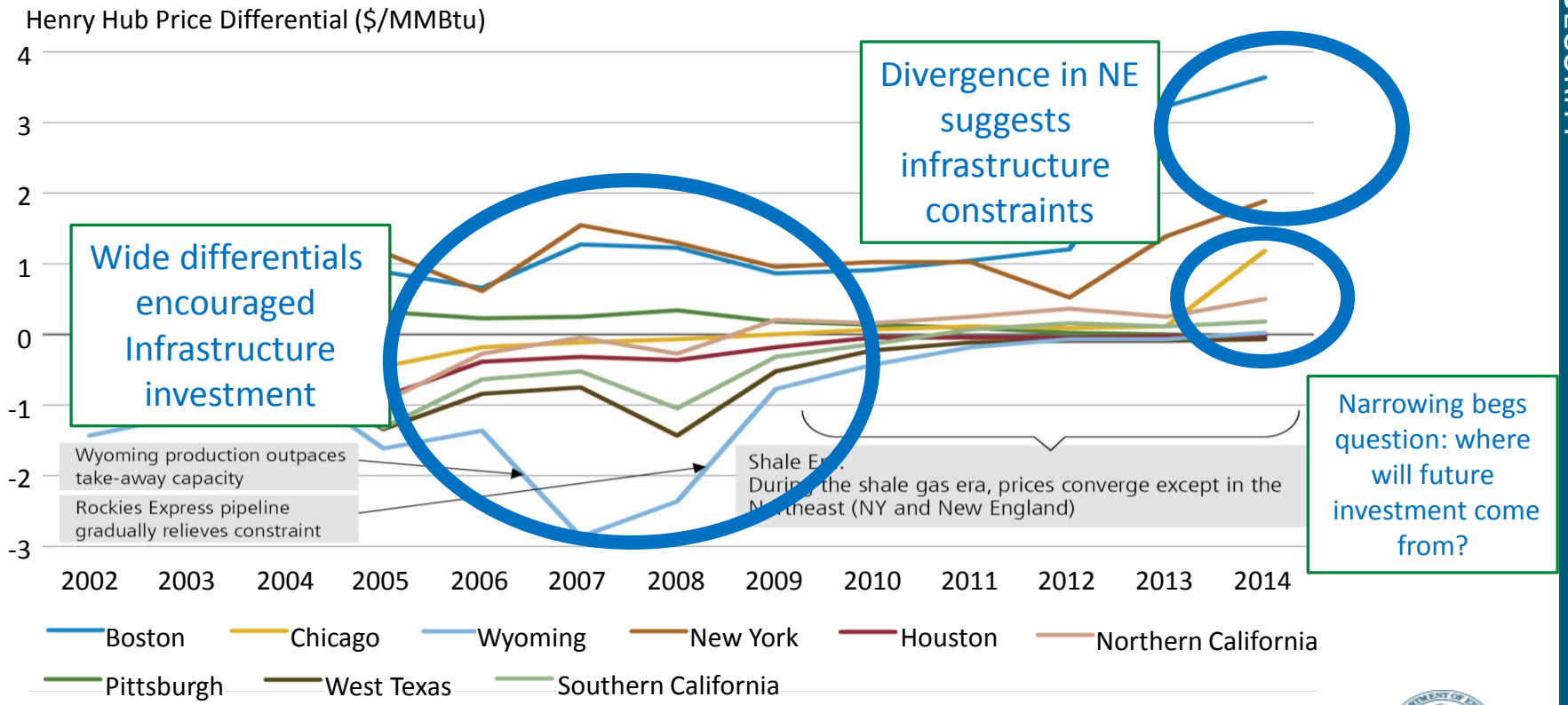
Trends of Increased Disruptions



Selected Findings

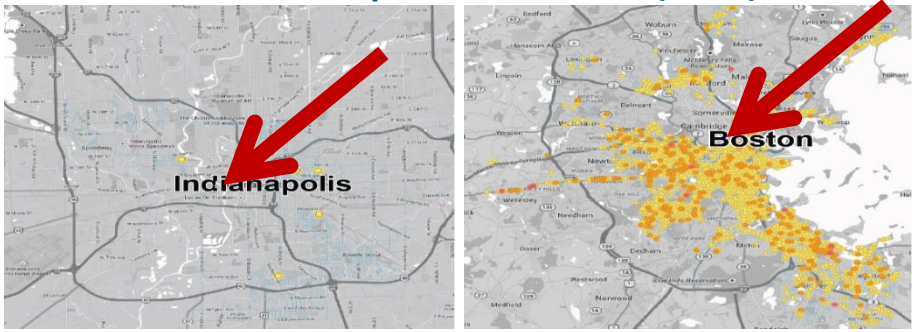
- Mitigating energy disruptions is fundamental to infrastructure resilience
- TS&D infrastructure is vulnerable to many natural phenomena, and some extreme weather events have become more frequent; threats and vulnerabilities vary substantially by region
- Cyber incidents and physical attacks are growing concerns
- High-voltage transformers are critical to the grid
- Aging, leak-prone natural gas distribution pipelines and associated infrastructures prompt safety and environmental concerns

Importance of Gas Transmission Infrastructure



Leak Prone Pipes in Local Distribution Systems

Methane Emissions from Natural Gas Distribution Systems in Indianapolis and Boston (2013)



Public safety risks from distribution pipelines

- Safety incidents are relatively infrequent, but increase as systems age
- The most leak-prone distribution pipeline materials -- cast iron and bare steel – can still be found in states across the country
- Many companies, states, and localities have taken action to improve safety by accelerating distribution pipeline replacement
- Cost concerns are a barrier to accelerated investment
- Methane leak mapping in Indianapolis and Boston show effect of newer vs. older pipelines

Expected Replacement Horizons for Select Utilities for Leak-Prone Mains (Forecasted Timeframe in Years)

Utility Company	Service Territory	State	Forecasted Timeframe (years)
Philadelphia Gas Works	Philadelphia, PA	PA	84
ConEd	New York, NY	NY	35
PECO	Greater Philadelphia, PA	PA	33
PSE&G	Newark, NJ	NJ	30
Pensacola Energy	Pensacola, FL	FL	30
Baltimore Gas Company	Baltimore, MD	MD	30
UGI	Rural Pennsylvania	PA	27
Consumers energy	Detroit, MI	MI	25
DTE	Detroit, MI	MI	25
National Grid	New York, NY	NY	25
Dominion Hope Gas Co.	Ohio	OH	20
Yankee Gas Service Company	Rural Connecticut	CT	20
Peoples Gas	Chicago, IL	IL	20
National Grid – Niagra Mohawk	Rhode Island	RI	19
Peoples TWP	Southwestern Pennsylvania	PA	19
Peoples Natural Gas Co.	Southwestern Pennsylvania	PA	17
National Grid – Niagra Mohawk	Syracuse, NY	NY	16
Columbia Gas of Pennsylvania	Southwestern Pennsylvania	PA	15
Northern Utilities	Maine	ME	13
CenterPoint	Arkansas	AR	12

States with Most Cast and Wrought Iron Pipelines
New Jersey
New York
Massachusetts
Pennsylvania
Michigan
Illinois
Connecticut
Maryland
Alabama
Missouri

States With Most Bare Steel Pipelines
Ohio
Pennsylvania
New York
Texas
Kansas
California
West Virginia
Oklahoma
Massachusetts
New Jersey

Regional Fuel Resiliency Studies

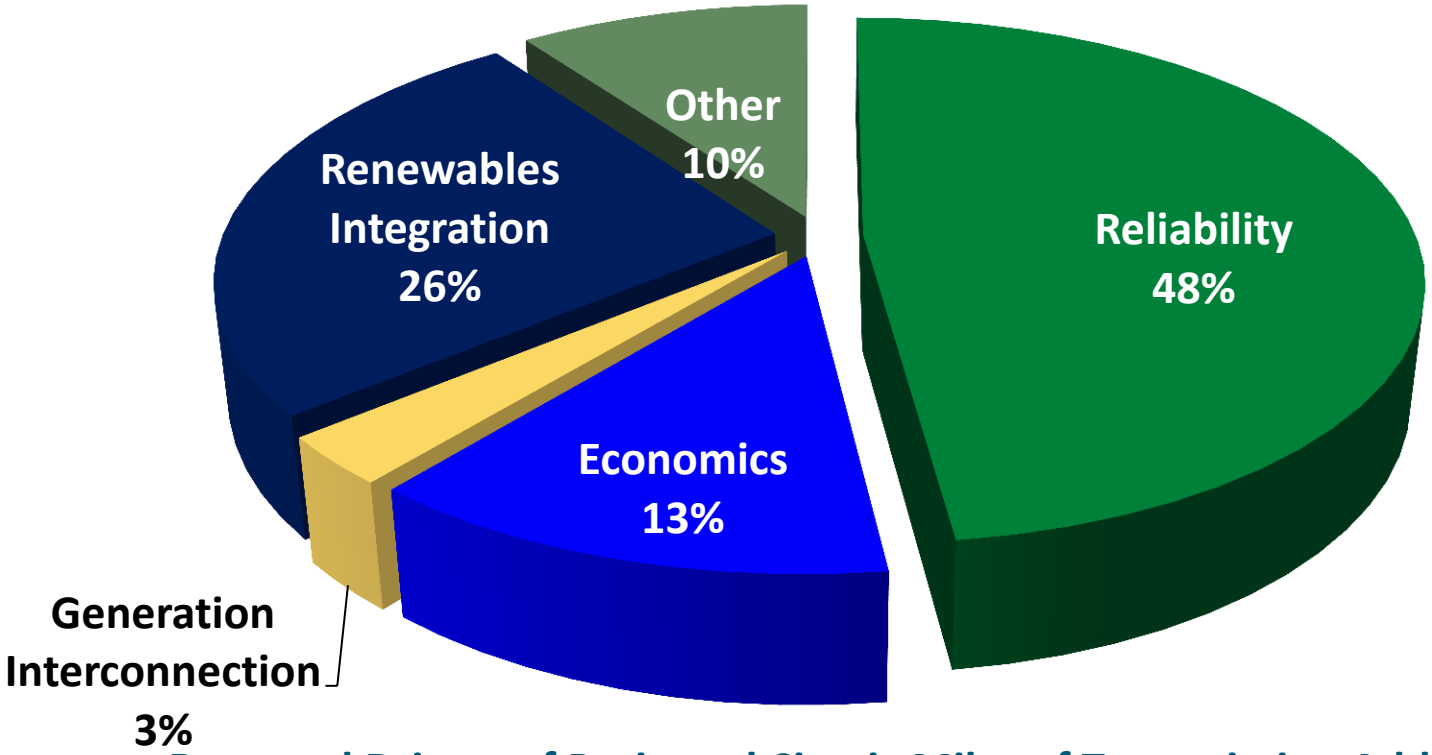
Far West. Increasingly depends on receiving shipments by water from other regions and from ports within region, including Alaska. Not well-connected to other PADDs by pipeline, receive s an increasing amount of its oil by rail. Susceptible to earthquakes and wildfires.

Southeast. Florida is heavily dependent on receiving water shipments of refined products. The interior is dependent on pipeline shipment of refined products from the Colonial and Plantation pipelines. Susceptible to weather disruptions of receiving ports, pipeline shipments,

Upper Rocky Mountains. This region consumes fuels from refineries in the Salt Lake and Denver areas. Main hazards are earthquakes and extreme cold. Pipelines networks are less dense , leading to cities that are far from refining centers often served by long dedicated pipelines.

MODERNIZING THE ELECTRIC GRID

Transmission Investment: Drivers



Reported Drivers of Projected Circuit-Miles of Transmission Additions (2011-2015)

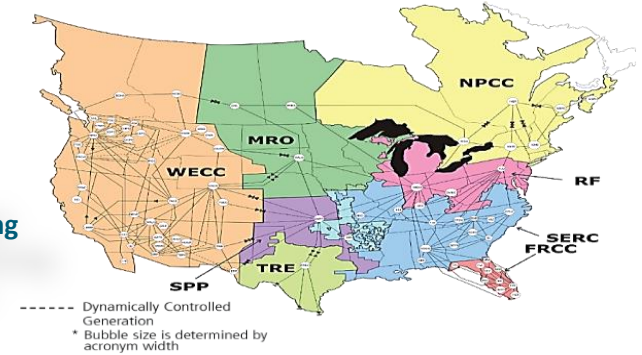
As reported voluntarily to NERC and in EIA form 411 by
IOUs, coops-munis, state/federal power agencies, ISOs/RTOs, and merchant developers

Recommendations and Jurisdictional Landscape

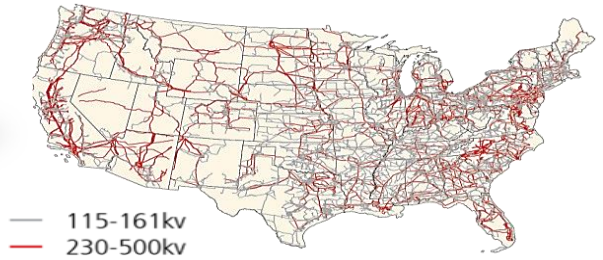
Selected Recommendations

- Provide $3.5 B in grid modernization research and development, analysis, and institutional support
- Conduct a national review of transmission plans and assess barriers to their implementation
- Provide $300-$350 M in state financial assistance to promote and integrate transmission, storage, and distribution infrastructure investment plans for electricity reliability, affordability, efficiency, lower carbon generation, and environmental protection
- Value new services and technologies
- Improve grid communication through standards and interoperability

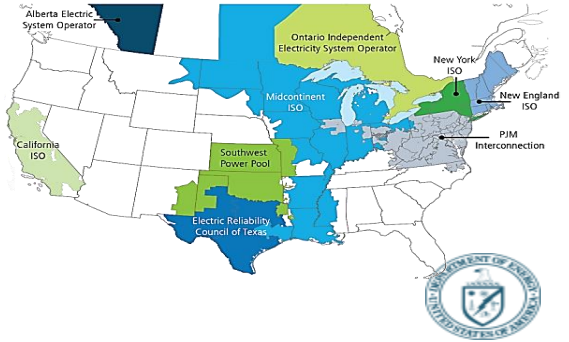
NERC Regional Entities and Balancing Authorities



Federally Regulated Power Lines



Regional Transmission Organizations (RTO)/ Independent System Operators (ISO)

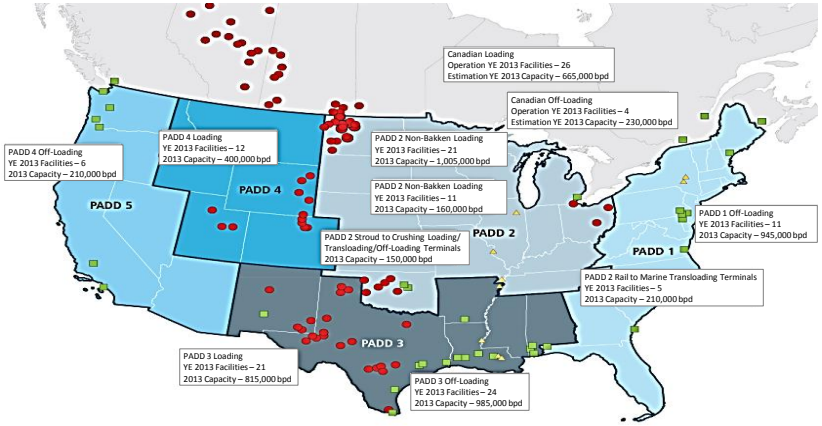


MODERNIZING U.S. ENERGY SECURITY INFRASTRUCTURES IN A CHANGING GLOBAL MARKETPLACE

Rapidly Changing Supply/Infrastructure Geography

Crude Oil by Train Loading (red) and Offloading (green) Facilities 2010

Crude Oil by Train Loading (red) and Offloading (green) Facilities 2013

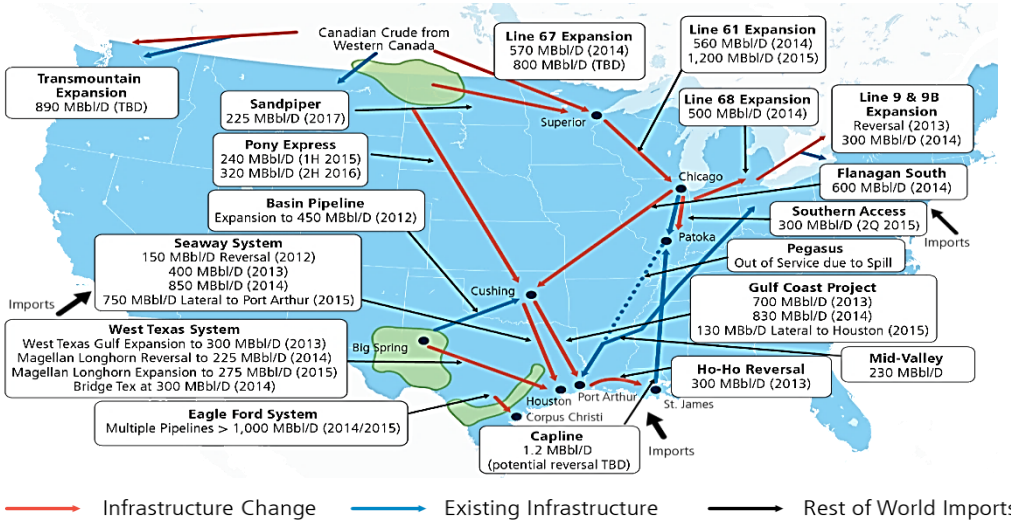


- In 2010, the United States and Canada had six rail loading facilities for crude oil and four offloading facilities

- By year-end 2013, crude oil by rail capacity had grown to include 65 loading facilities in Petroleum Administration Defense Districts (PADD) 2, 3, and 4. Rail-to-barge facilities also increased.

Findings

Highlighted Pipeline Reversals and Expansions Accommodating Increased Domestic and Canadian Supply



The Quadrennial Energy Review, April 2015

"The United States is now the world's largest producer of petroleum and natural gas. Combined with new clean energy technologies, and improved fuel efficiency, and growth in oil and natural gas production, U.S. energy security is stronger than it has been for over half a century."

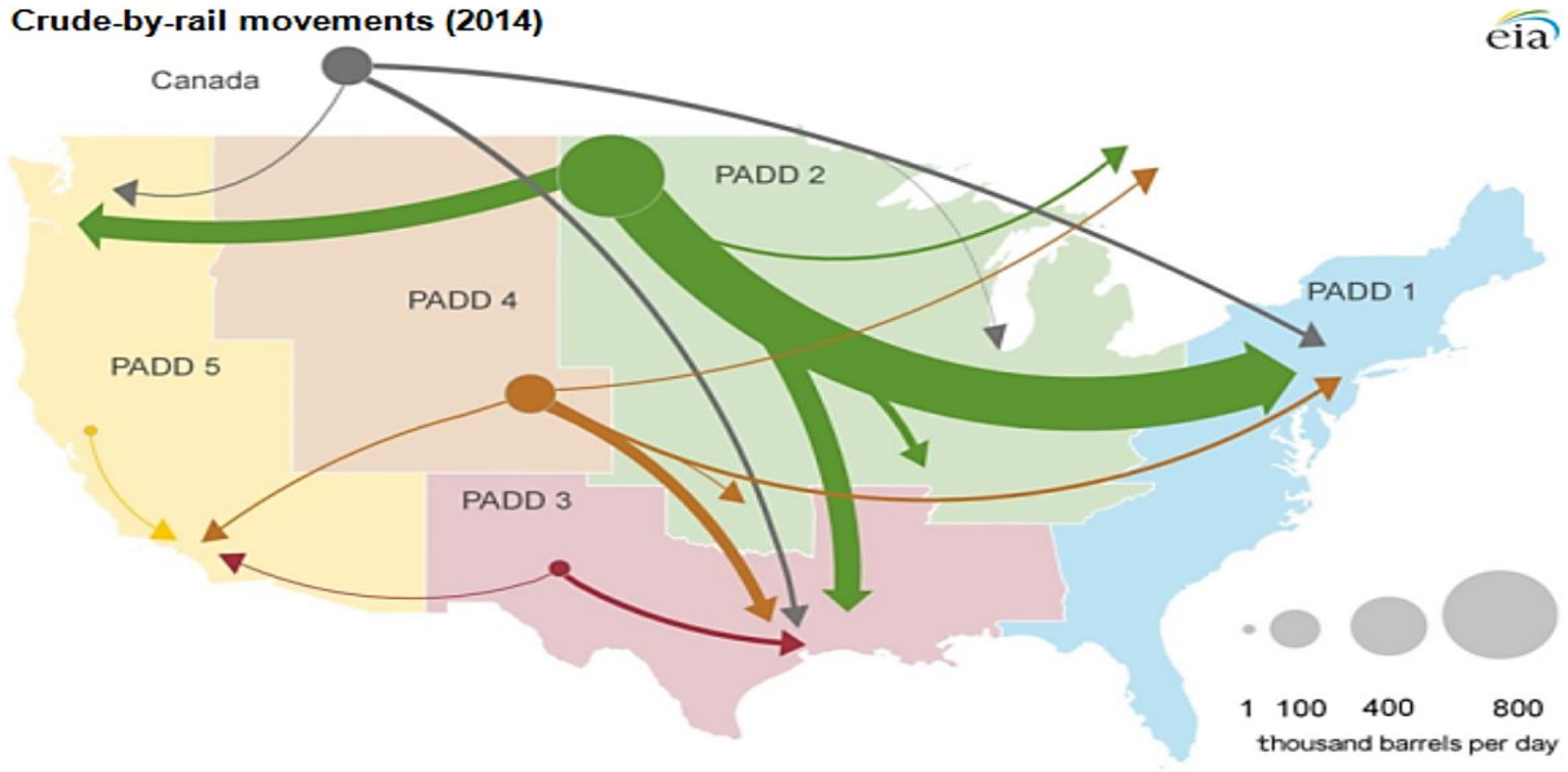
Selected Findings

- The United States has achieved unprecedented oil and gas production growth
- The network of oil distribution ("the midstream") has changed significantly
- The Strategic Petroleum Reserve's ability to offset future energy supply disruptions has been adversely affected by domestic and global oil market developments coupled with the need for upgrades
- Biofuel production in the United States has increased rapidly over the last decade, enhancing energy security and reducing greenhouse gases from transportation

IMPROVING SHARED ENERGY TRANSPORT INFRASTRUCTURES

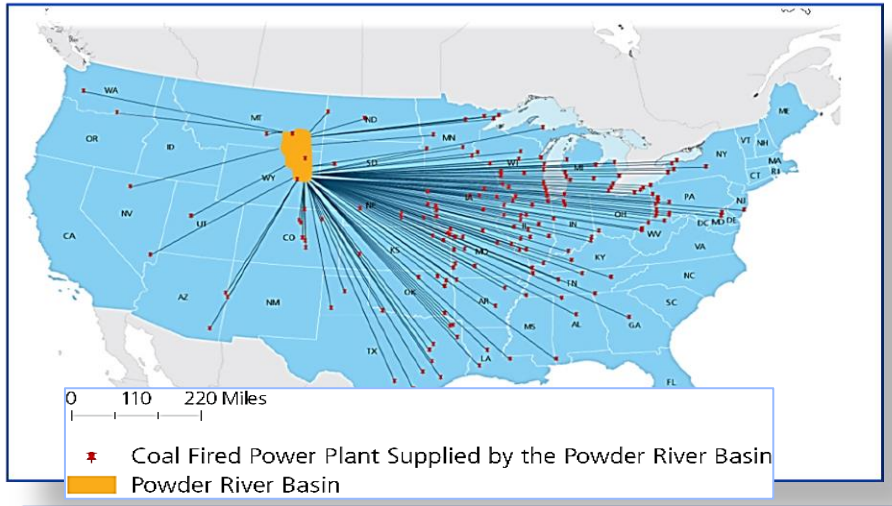
Rail Movements of Crude Oil, 2010-2014

2010 | 2011 | 2012 | 2013 | **2014**



Rail Trends

Coal-Fired Power Plants Supplied by the Powder River Basin



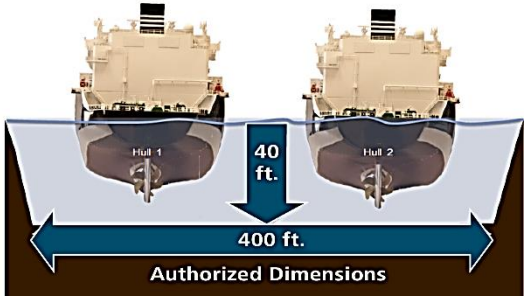
A study by USDA's Agricultural Marketing Service concluded that, for the period from August 2013 through August 2014,

"the magnitude and duration of recent unexpected shifts in supply and demand for … rail service… have exceeded previous events in terms of both magnitude and duration, including Hurricane Katrina, which caused major disruptions throughout the entire agricultural transportation network."

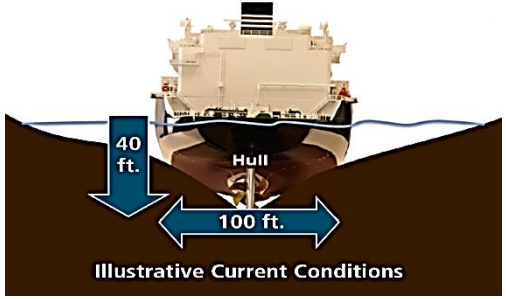
Key Rail Findings

- Oil is an attractive commodity for railroad as it is not seasonal
- On average, roughly 1 million barrels of oil were moved by rail per day in 2014—nearly 12 percent of U.S. domestic crude oil production
- 34 states get coal for power generation from the Powder River Basin in Wyoming, almost all by rail. Eight states obtain more than 90 percent of their domestic coal from Wyoming. It is largely transported through regions of rail congestion where much of our oil and agriculture also originate.

Ports and Waterways Trends



Calcasieu River Ship Channel – Lake Charles, LA - designed for two tankers to pass



Shoaling can force vessels to reduce cargos, idle until high-tide, or, be subject to one-way traffic restrictions

Top 10 Port Systems by Total Energy Commodity Shipments (2013, millions of short tons)

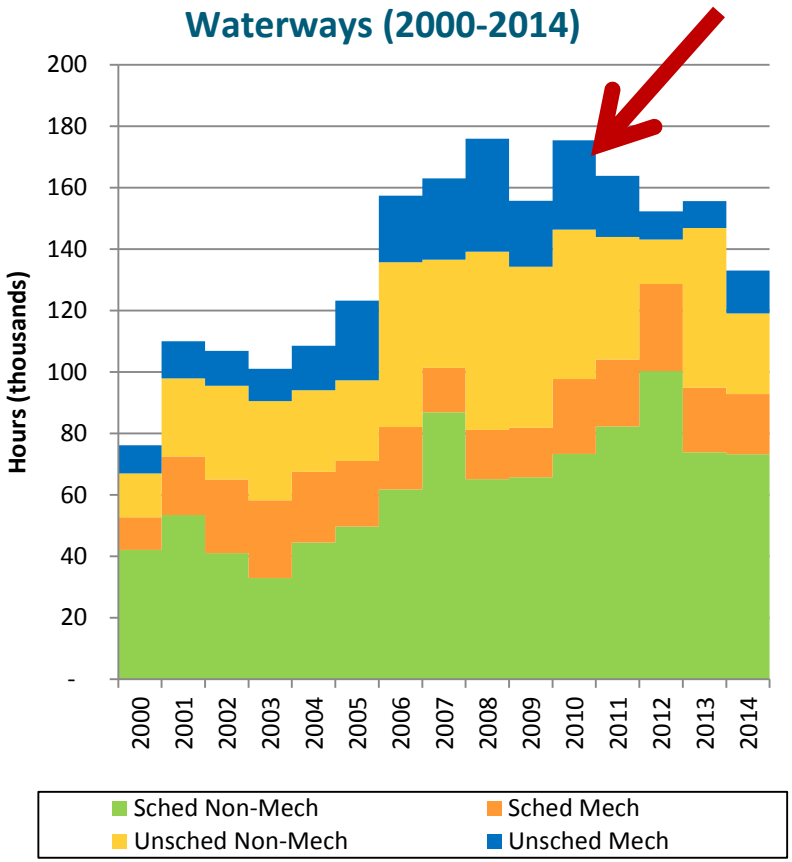
Port Channel System	Crude and Petroleum Products	Coal	Total Energy	Energy as a Percentage of Shipments
Lower Mississippi (LA)	161	47	208	48%
Houston/Galveston (TX)	200	3	203	69%
Beaumont/Port Arthur (TX)	115	-	115	89%
Port of NY/NJ	80	<1	80	59%
Delaware River	62	-	62	82%
Corpus Christi (TX)	58	-	58	77%
Port of Virginia	2	50	52	66%
Lake Charles (LA)	49	-	50	88%
LA and Long Beach (CA)	46	2	47	33%
Huntington - Tristate (WV)	8	32	41	87%

Selected Waterways Findings

- In 2012, crude oil, refined petroleum products, and coal were 55% of all U.S. waterborne cargo traffic by weight
- Nearly 15 percent of all petroleum products consumed in the U.S. are shipped on inland waterways
- DOT's Beyond Traffic 2045 report concludes that "... several critical trends will have a major impact on the performance of critical marine links in our transportation systems." They include:
  - Increasing imports and exports and containerized freight will lead to greater congestion on America's coastal and inland ports
  - Investment in ports, harbors, and waterways will be essential to meet the demand of increased trade and competition

Findings

Hours of Lock Unavailability on U.S. Inland Waterways (2000-2014)



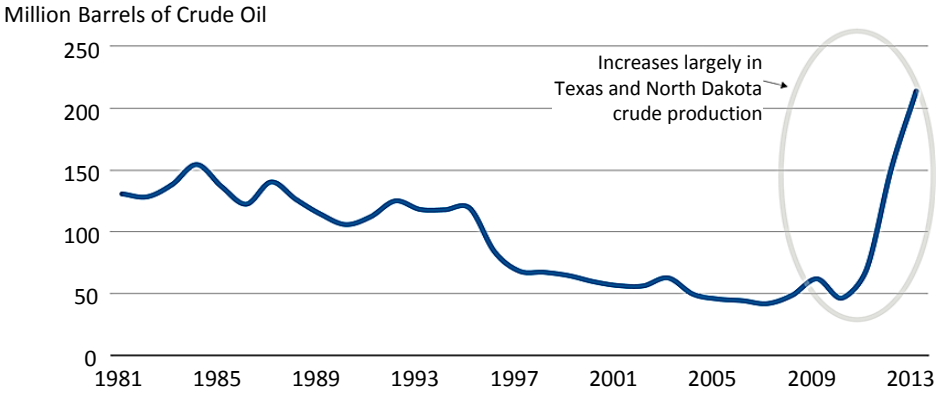
Selected Findings

- Rapid crude oil production increases have changed the patterns of flow of North American midstream (pipelines, rail, and barge) liquids transport infrastructure
- Limited infrastructure capacities are intensifying competition among commodities, with some costs passed on to consumers
- The ability to maintain adequate coal stockpiles at some electric power plants has been affected by rail congestion
- Funding for the U.S. freight transportation system is complex and involves a combination of Federal, state, local, and private investments
- Multi-modal shared transportation infrastructure is stressed by increased shipments of energy supplies, materials, and components

Findings

Recommendations

Domestic Crude Refinery Receipts by Barge (1981-2013)

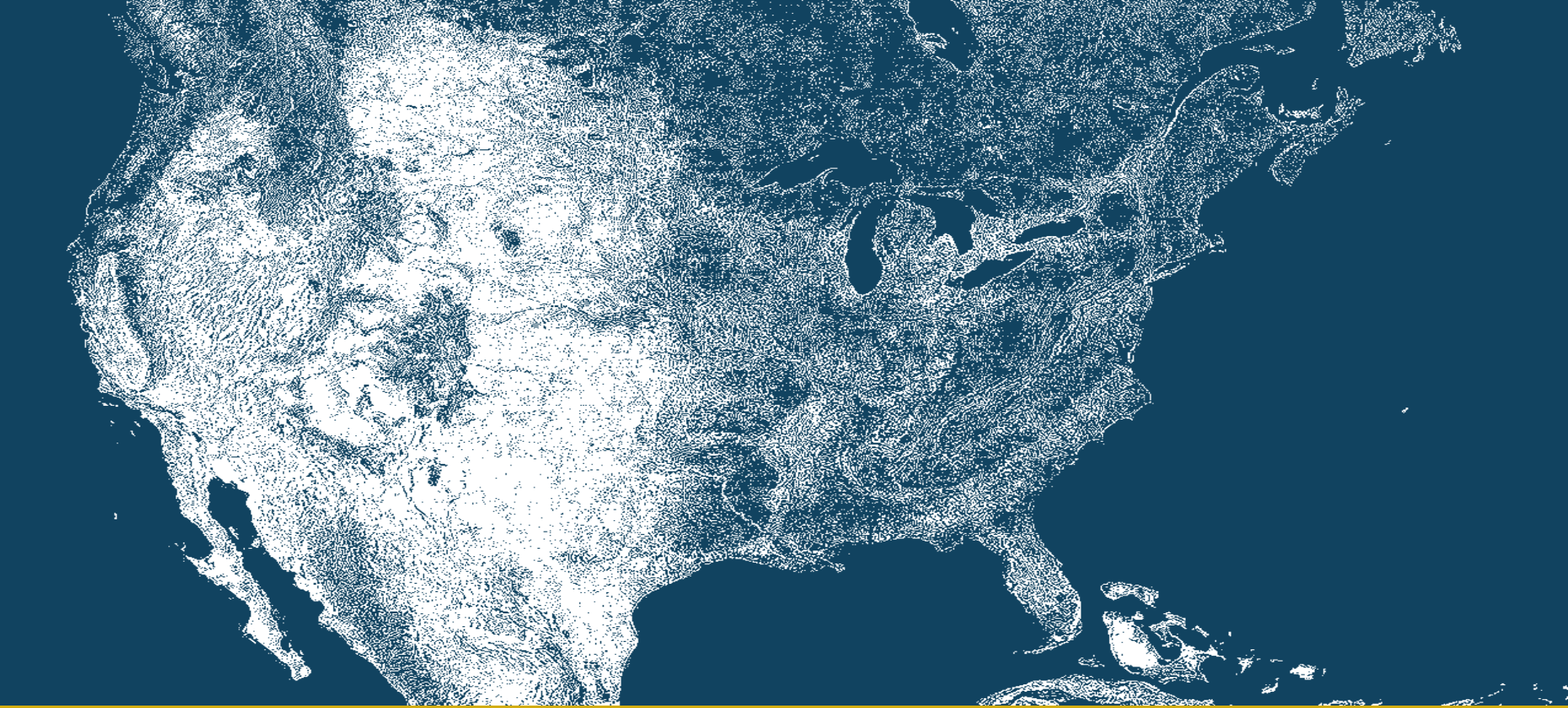


The Quadrennial Energy Review, April 2015

"Changes in the U.S. energy marketplace are stressing the Nation's infrastructures… particularly in the case of oil where the rapid increase in U.S. tight oil production is transforming conventional patterns and modes."

Selected Recommendations

- Support a $2 - $2.5 B program of competitively awarded grants for shared energy transport systems
- Enhance the understanding of important safety-related challenges of transport of crude oil and ethanol by rail and accelerate responses
- Address critical energy data gaps in the rail transport of energy commodities and supplies
- Support alternative funding mechanisms for waterborne freight infrastructure
- Support public-private partnerships for waterborne transport infrastructure



INTEGRATING NORTH AMERICAN ENERGY MARKETS

Findings and Recommendations

Selected Findings

- The United States has robust energy trade with Canada and Mexico, and increasingly in the Caribbean region. This presents abundant opportunities for increased integration of markets and policies.
- There is an opportunity to lower Caribbean electricity costs and emissions

Selected Recommendations

- Continue advances that have been made in the North American energy dialogue
- Increase the integration of energy data among the United States, Canada, and Mexico
- Undertake comparative and joint energy system modeling, planning, and forecasting
- Establish programs for academic institutions and not-for-profits to develop legal, regulatory, and policy roadmaps for harmonizing regulations across borders
- Coordinate training and encourage professional interactions
- Partner with Canada and the Arctic Council on Arctic energy safety, reliability, and environmental protection
- Partner with Canada and the Arctic Council on energy delivery to remote areas
- Promote Caribbean energy TS&D infrastructure

North American Energy Flows