QUADRENNIAL ENERGY REVIEW

ENERGY TRANSMISSION, STORAGE, AND DISTRIBUTION INFRASTRUCTURE

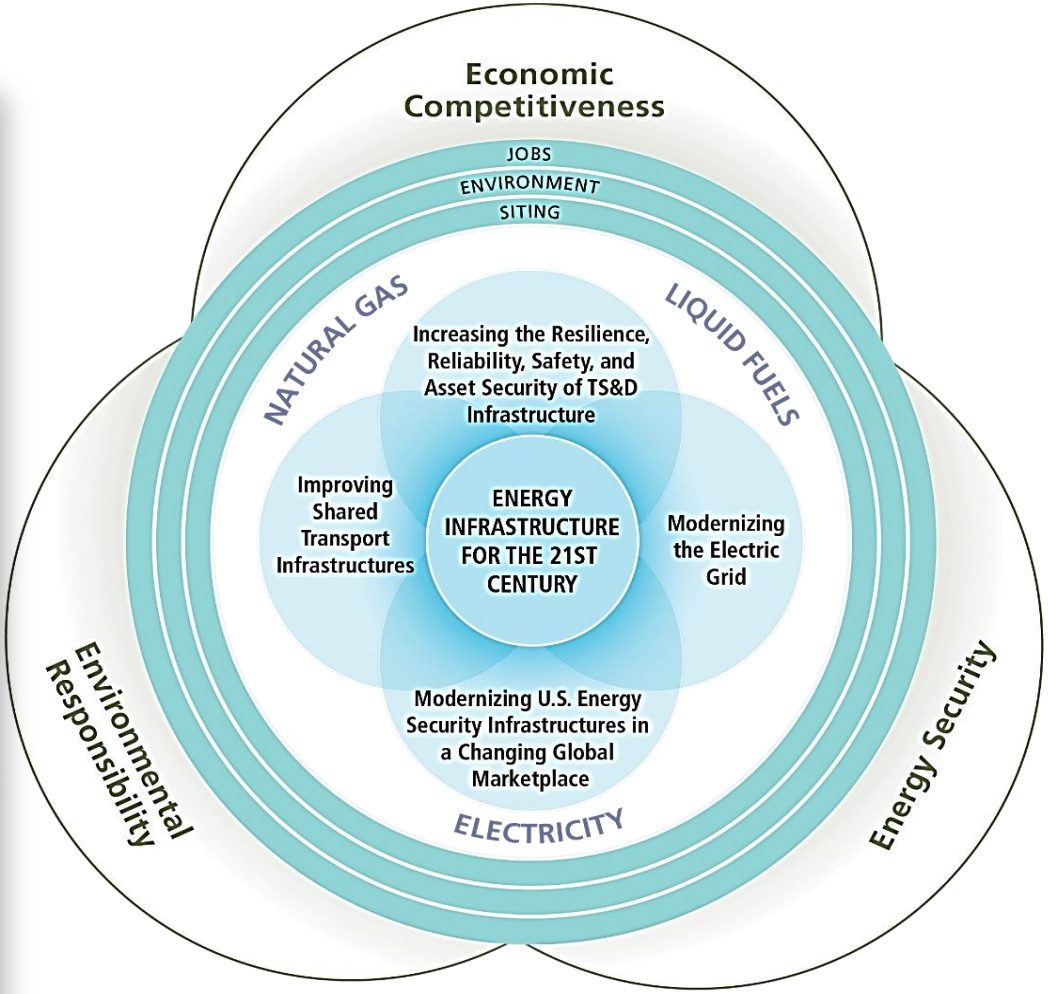
Energy Security and the Quadrennial Energy Review

Center for Strategic & International Studies

July 14, 2015

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



High Level Goals Energy Infrastructure Objectives Crosscutting Issues

The QER on the Rome G-7 Energy Security Principles

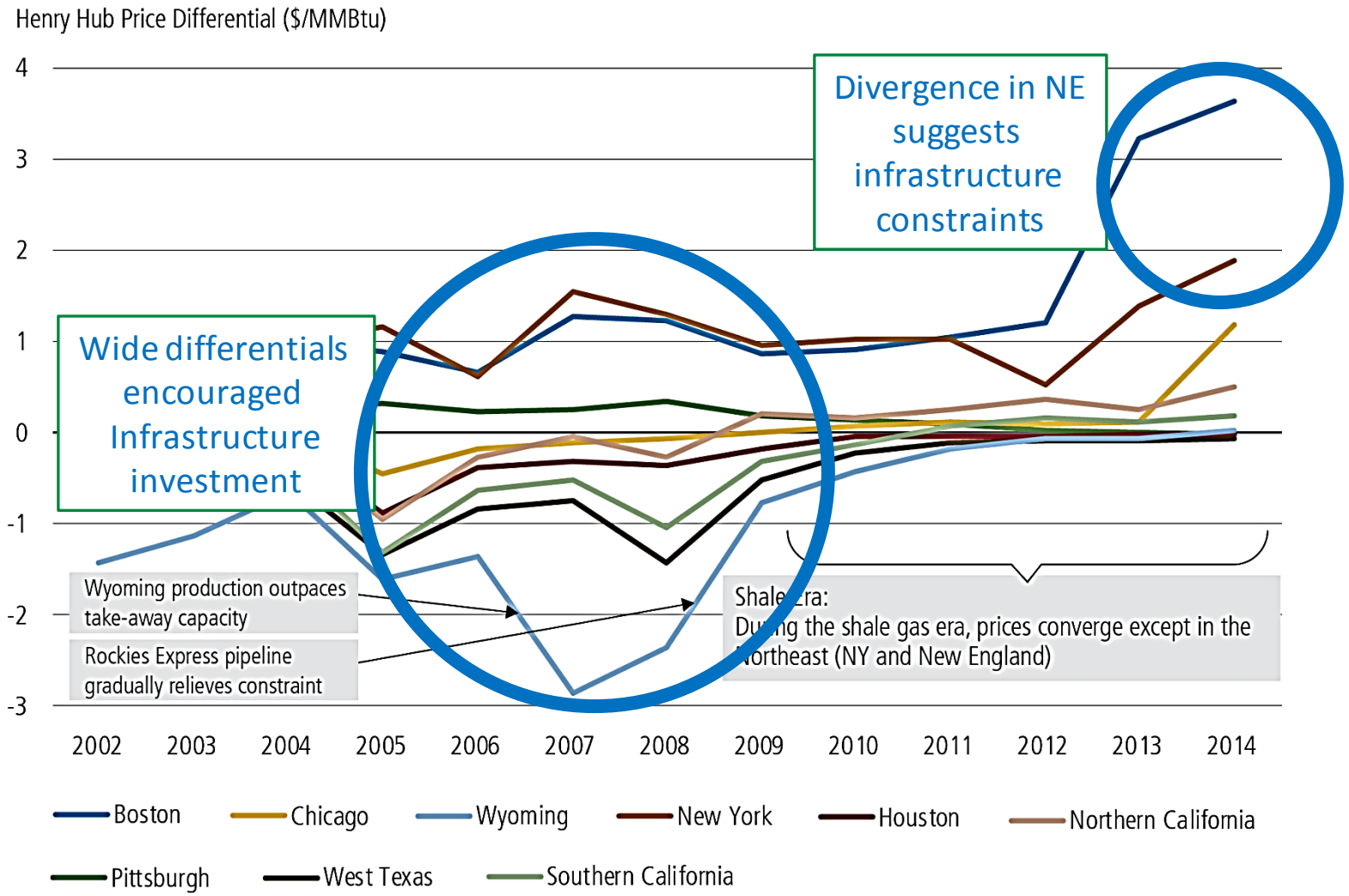
"Energy security is not only domestic – it is dependent on interaction in the global interconnected market. Acknowledging the need for a modern and collective definition of energy security...the G-7 Ministers adopted a set of seven principles:

- Development of **flexible, transparent and competitive energy markets, including gas markets.**
- **Diversification of energy fuels, sources and routes,** and encouragement of indigenous sources of energy supply.
- **Reducing our greenhouse gas emissions,** and accelerating the transition to a low carbon economy, as a key contribution to enduring energy security.
- **Enhancing energy efficiency in demand and supply**, and demand response management.
- **Promoting deployment of clean and sustainable energy technologies** and continued investment in research and innovation.
- **Improving energy systems resilience** by promoting infrastructure modernization and supply and demand policies that help withstand systemic shocks.
- **Putting in place emergency response systems,** including reserves and fuel substitution for importing countries, in case of major energy disruptions."

Development of flexible, transparent and competitive energy markets, including gas markets

Diversification of energy fuels, sources and routes, and encouragement of indigenous sources of energy supply

Importance of Gas Transmission Infrastructure



Competitive Energy Markets Enhance Industrial Base

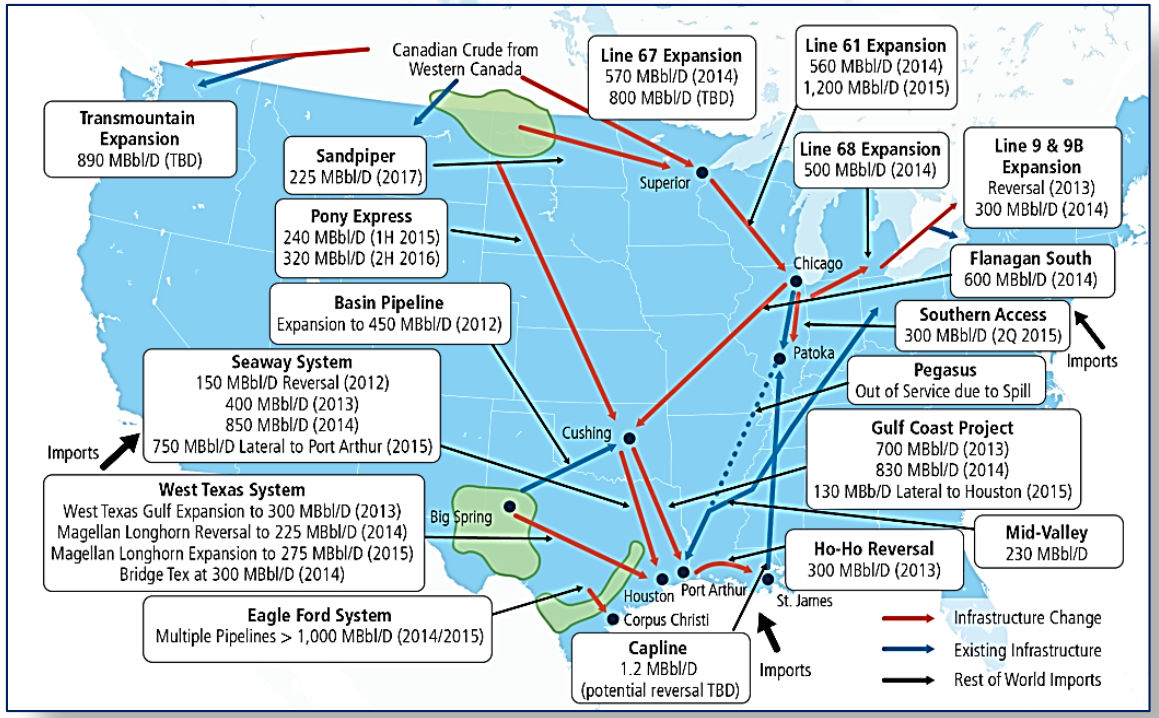
New Industrial Natural Gas Related Projects, 2015-2020

Planned Operations Date	Chemical		Metals		Petroleum		Other Industrial		Total Demand	
Year	MMcf/d	# Projects	MMcf/d	# Projects	MMcf/d	# Projects	MMcf/d	# Projects	MMcf/d	# Projects
2015	246	57	118	54	355	21	24	179	743	311
2016	317	13	62	5	488	10	58	27	926	55
2017	261	5	79	3	325	3	2	8	668	19
2018	265	5	1	1	747	5	0	4	1,010	15
2019	-	-	-	-	1,350	4	-	-	1,350	4
2020	-	-	-	1	-	-	-	-	-	1
Project dates not announced*	179	6	2	3	872	5	-	-	1,050	14
Total	1,090	80	261	64	3,260	43	86	218	4,700	405

* Not announced at time of this analysis, 6/2014

Diversification of Liquid Fuels Infrastructure Needed for New Supplies

Highlighted Pipeline Reversals and Expansions Accommodating Increased Domestic and Canadian Supply



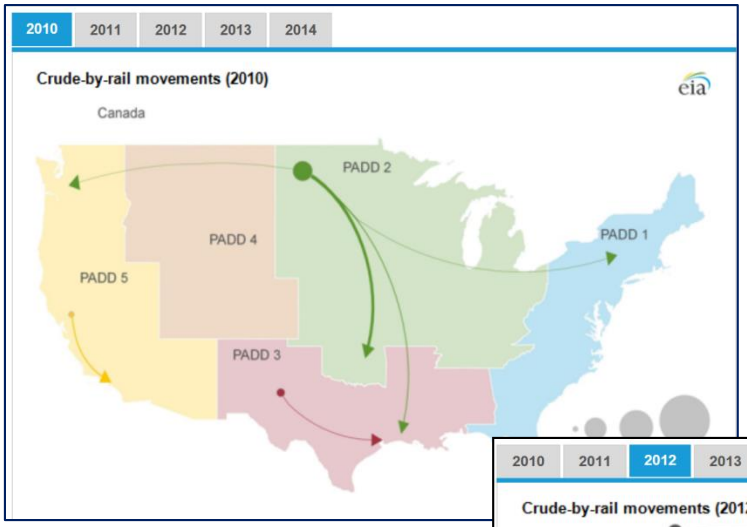
The Quadrennial Energy Review, April 2015

"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."

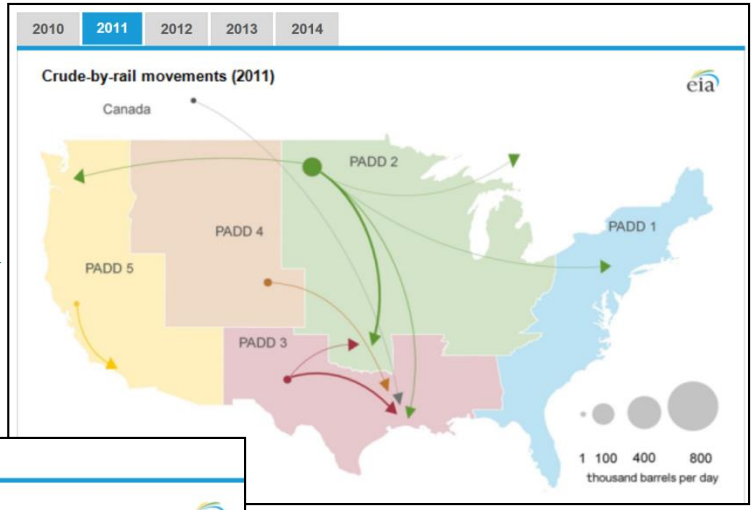
Selected Findings

- 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

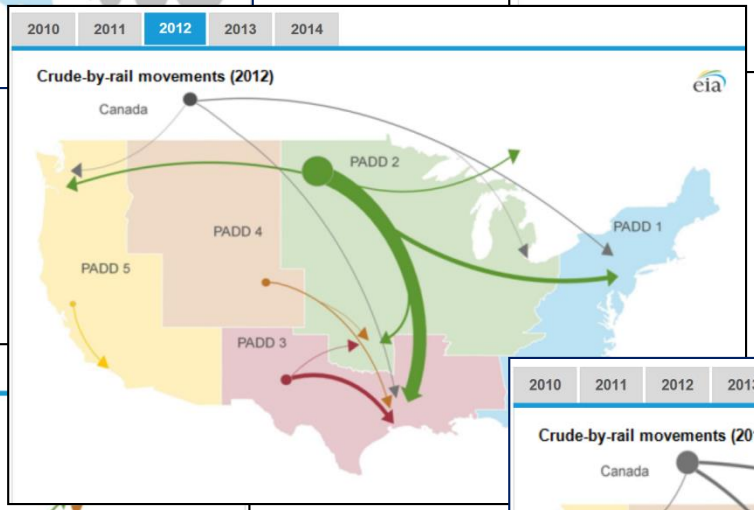
Crude Oil by Rail Increases and Changes in Directional Flows, 2010-2014



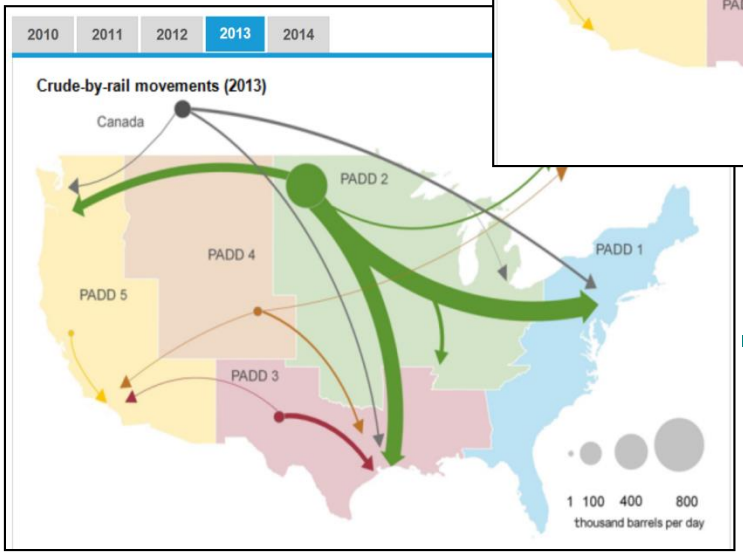
2010-2011



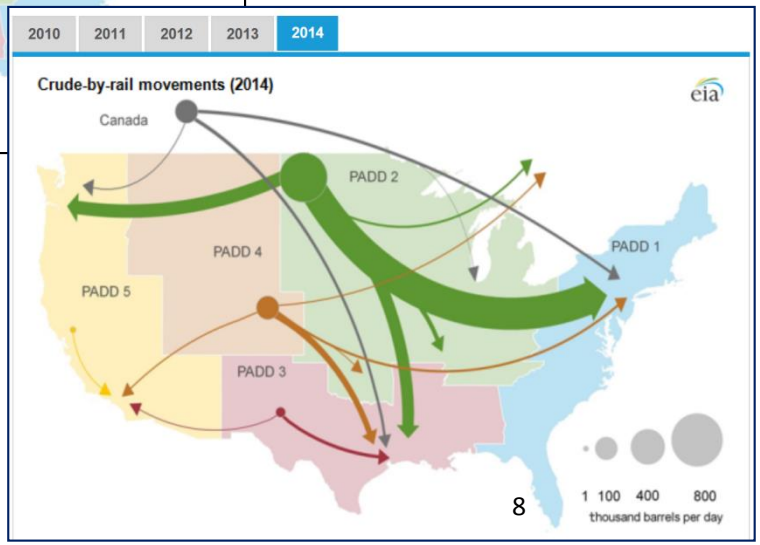
2011-2012



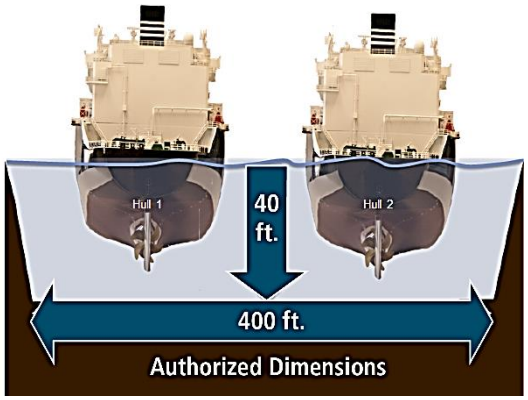
2012-2013



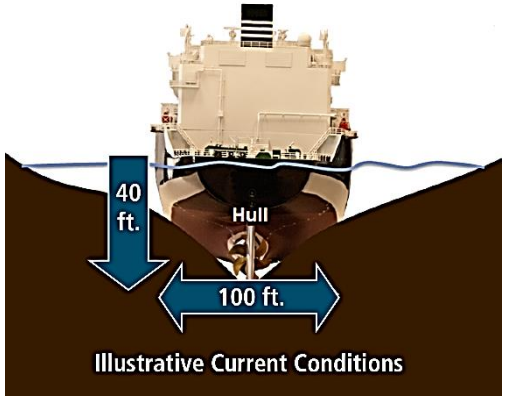
2013-2014



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 and Recommendations

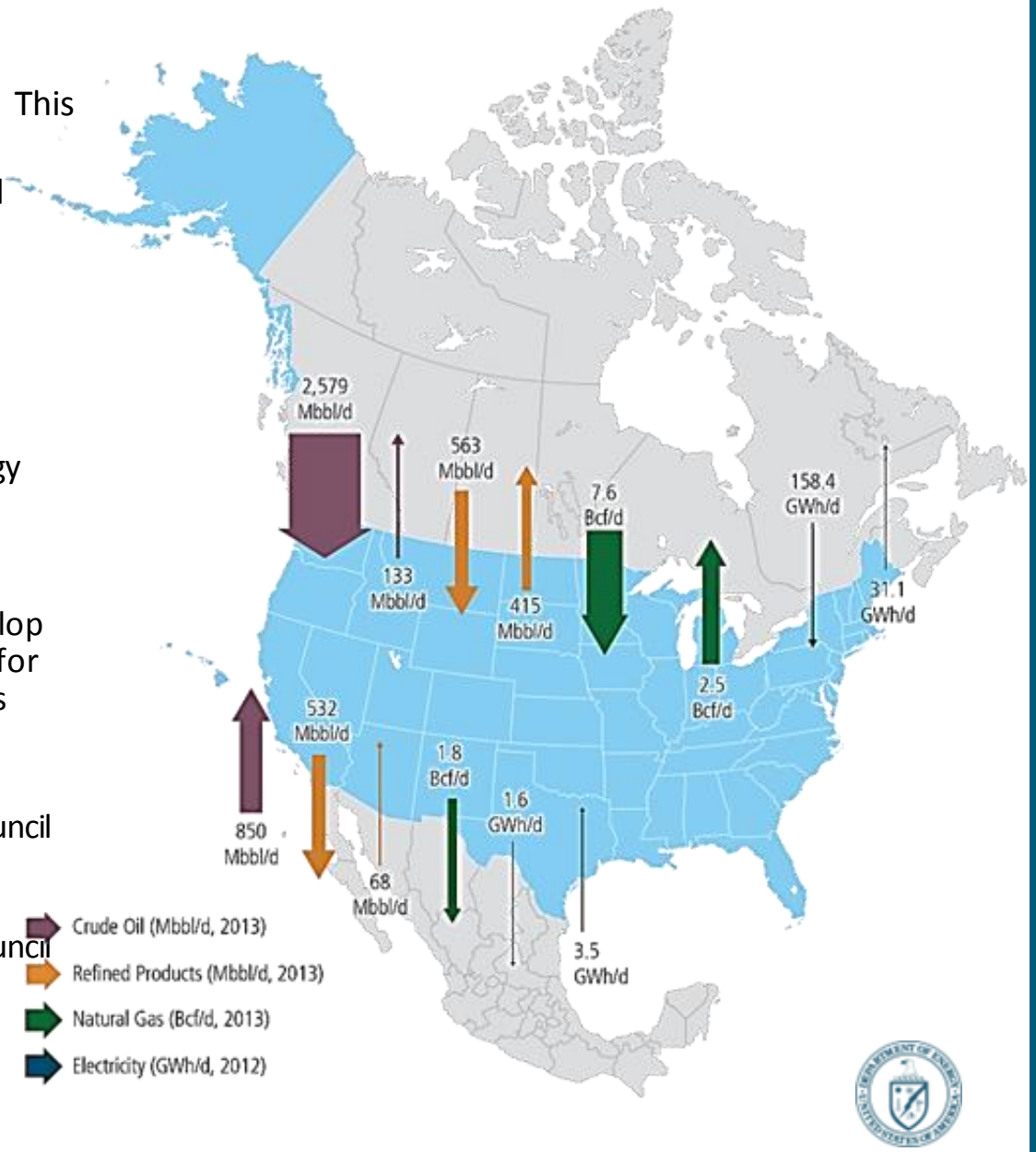
Selected Findings

- 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.

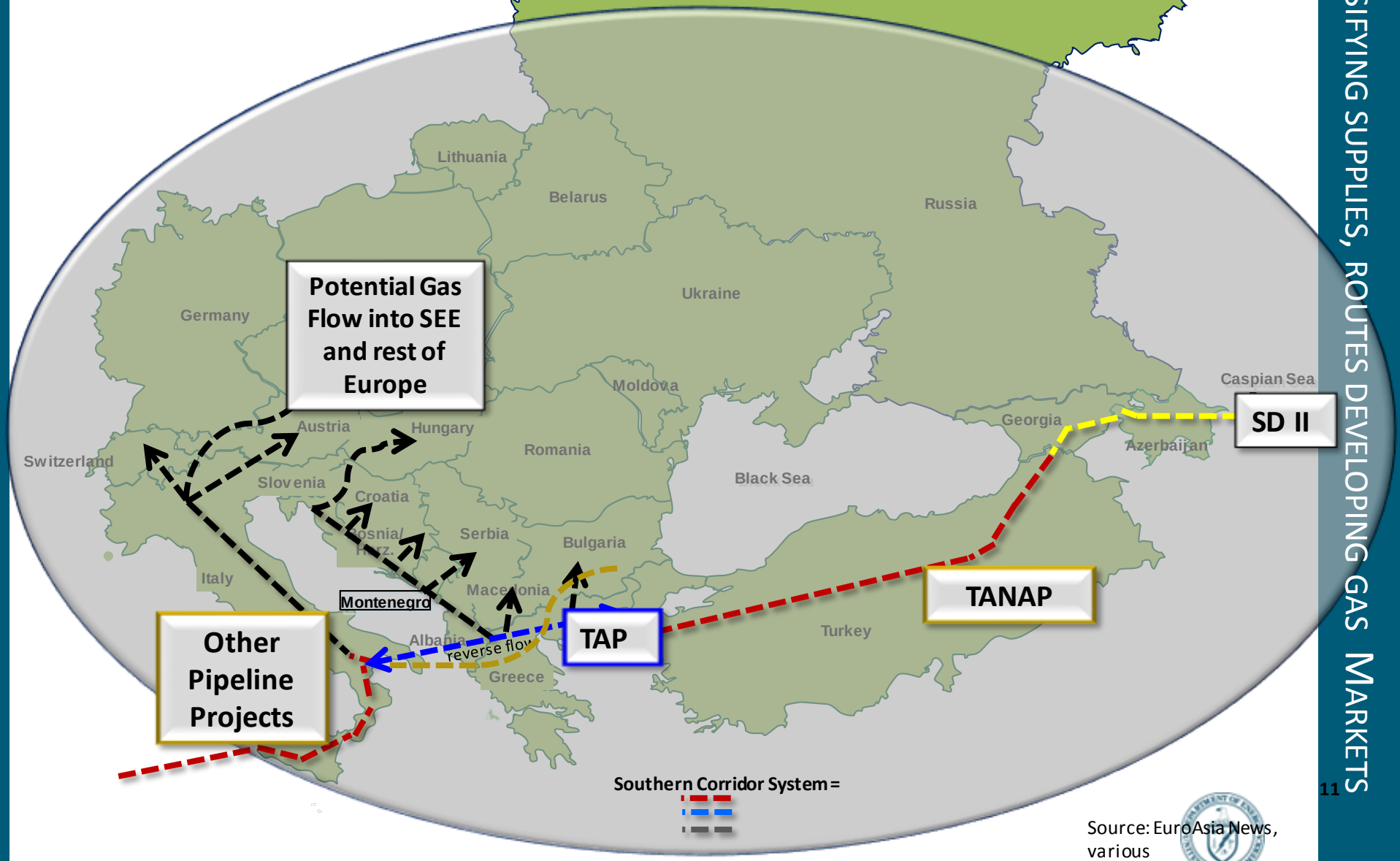
Selected Recommendations

- 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



Southern Corridor: Diverse Suppliers, Routes



Source: EuroAsia News, various

Turkey as a Natural Gas Hub

Turkey's President Erdogan, March 2015

- "We plan to establish Turkey as the energy distribution hub of the region."
- "TANAP has a special importance because of its route and its goal. It is not an alternative project to others; there is no alternative to it"

Source: Reuters

Competitive Gas Markets

Natural Gas Hub: Henry Hub is the current price setting hub in the U.S. Henry Hub consists of:

- 9 interstate pipelines
- four intrastate pipelines
- two compressors
- the capacity to transport 1.8 bcfd or 590 mcm/day of natural gas

In short, Henry Hub is a hub by virtue of its diversity of supplies and the robustness of its infrastructure

Market Power: The ability to engage in unilateral anti-competitive behavior. A firm (or country) with market power has the ability to individually affect either the total quantity of the prevailing market price of a commodity, good or service. From an international perspective, market power = the ability to use a commodity, e.g., natural gas, as a geopolitical weapon.

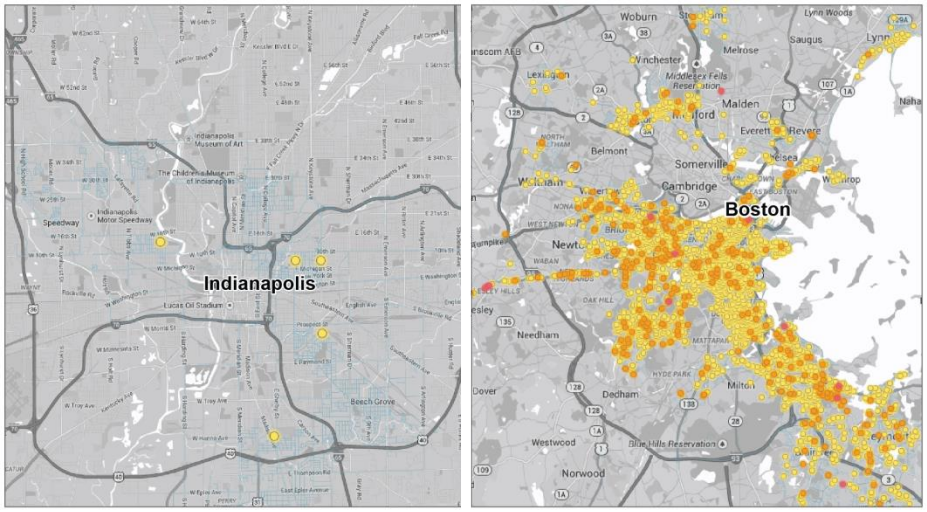
Reducing our greenhouse gas emissions, and accelerating the transition to a low carbon economy, as a key contribution to enduring energy security.

Enhancing energy efficiency in demand and supply, and demand response management.

Promoting deployment of clean and sustainable energy technologies and continued investment in research and innovation.

Leak Prone Pipes in Local Distribution Systems

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



Select Findings

- Safety incidents are relatively infrequent, but increase as systems age
- The most leak-prone distribution pipeline materials are cast iron and bare steel
- Many companies, states, and localities have taken action to improve safety by accelerating distribution pipeline replacement
- Methane leak mapping in Indianapolis and Boston show effect of newer vs. older pipelines

Select Recommendation

- Establish a $2.5 - $3.5 B competitive financial assistance program to accelerate pipeline replacement and enhance maintenance programs for natural gas distribution systems

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

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 Services 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

15

States with Most Cast and Wrought Iron Pipelines

New Jersey
New York
Massachusetts
Pennsylvania
Michigan
Illinois
Connecticut
Maryland
Alabama
Missouri

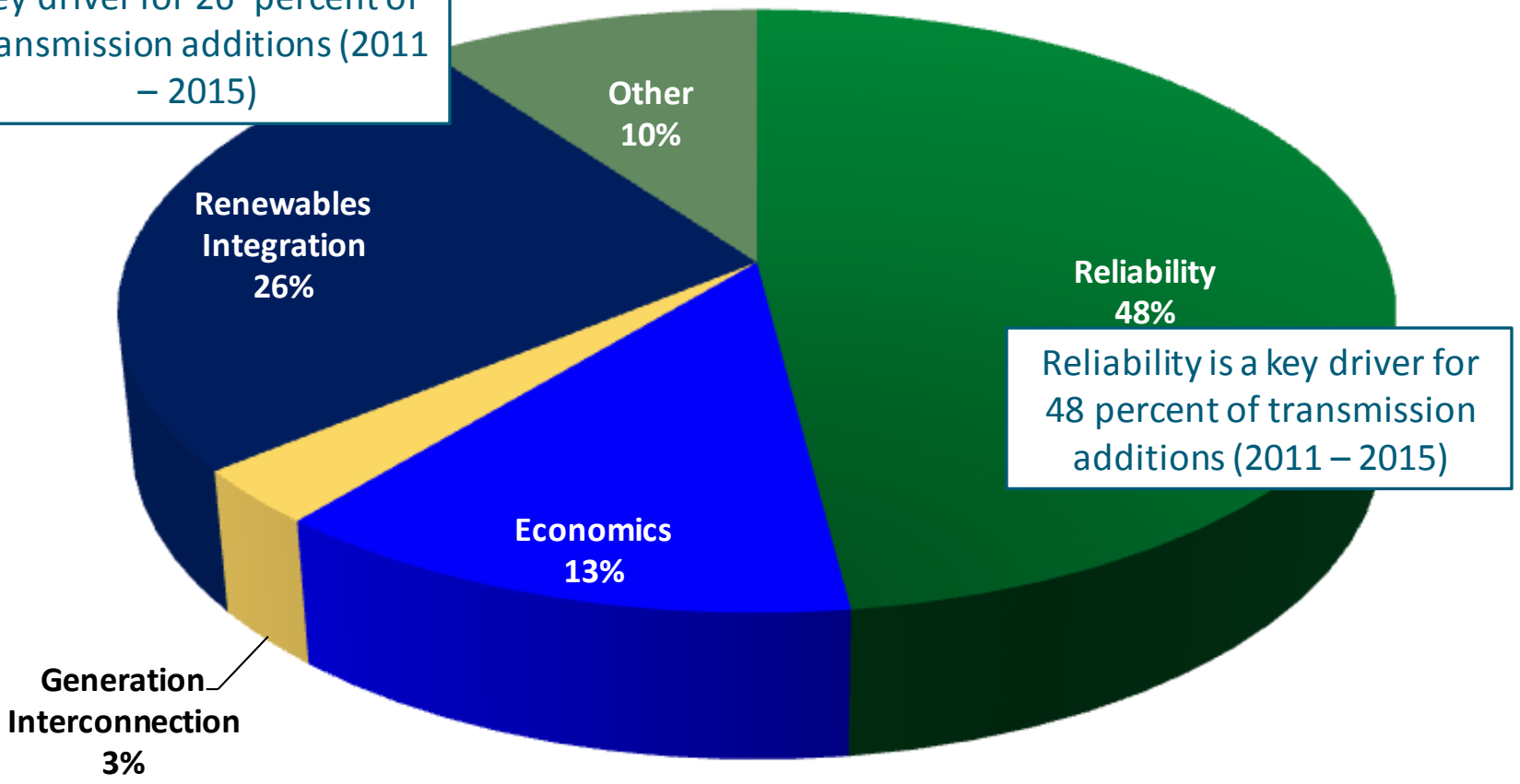
States With Most Bare Steel Pipelines

Ohio
Pennsylvania
New York
Texas
Kansas
California
West Virginia
Oklahoma
Massachusetts
New Jersey

INCREASING RESILIENCE, RELIABILITY, SAFETY, AND ASSET SECURITY

Transmission Investment: Drivers

Renewables integration is a key driver for 26 percent of transmission additions (2011 – 2015)



Reliability is a key driver for 48 percent of transmission additions (2011 – 2015)

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

Valuing Efficiency, Demand Response and Distributed Generation Key to Clean Energy

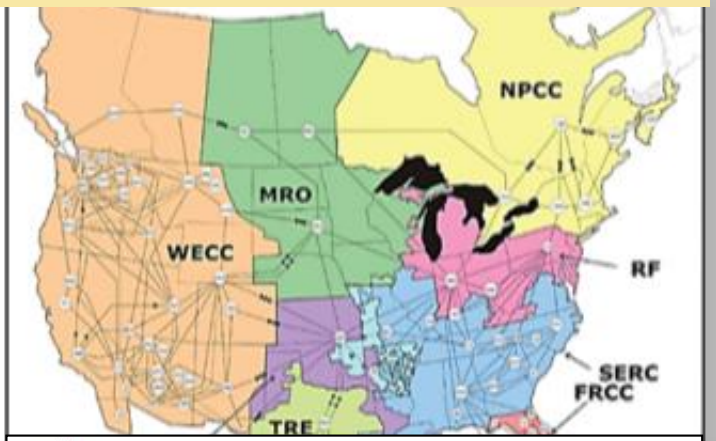
Grid Component/Opportunity	Description
AC/DC power flow controllers/converters	Technologies that adjust power flow at a more detailed and granular level than simple switching.
Advanced multi-mode optimizing controls	Controls capable of integrating multiple objectives and operating over longer time horizons, to replace simple manual and tuning controls, or controls that operate based only on conditions at single points in time.
Bilaterally fast storage	Energy storage in which charge and discharge rates are equally fast and thus more flexible.
Control frameworks	New hybrid centralized/distributed control elements and approaches.
Management of meta-data, including network models	New tools for obtaining, managing, and distributing grid meta-data, including electric network models.
Synchronized distribution sensing	Synchronization of measurements in order to provide more accurate snapshots of what is happening on the grid.
Transactive buildings	Buildings with controls and interfaces that connect and coordinate with grid operations in whole-grid coordination frameworks.
"X"-to-grid interface and integration	Interface technologies, tools, and standards for the general connection of energy devices to power grids; includes integrated mechanisms for coordinating those devices with grid operations in whole-grid coordination frameworks.
Distribution System Operation	Structure for clear responsibility for distributed reliability.

Recommendations to Modernize the Electric Grid

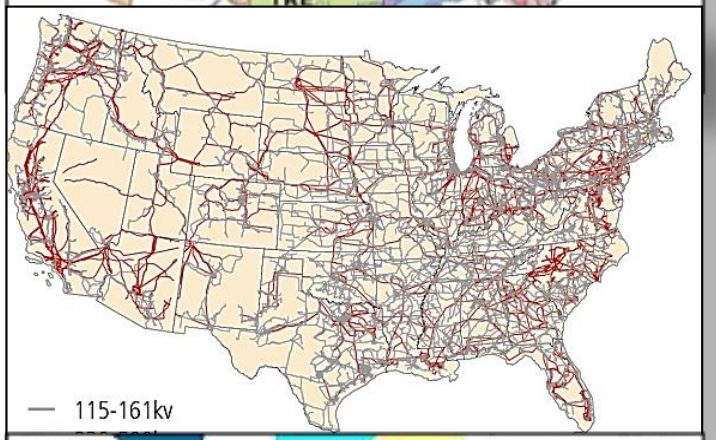
Selected Recommendations

- 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

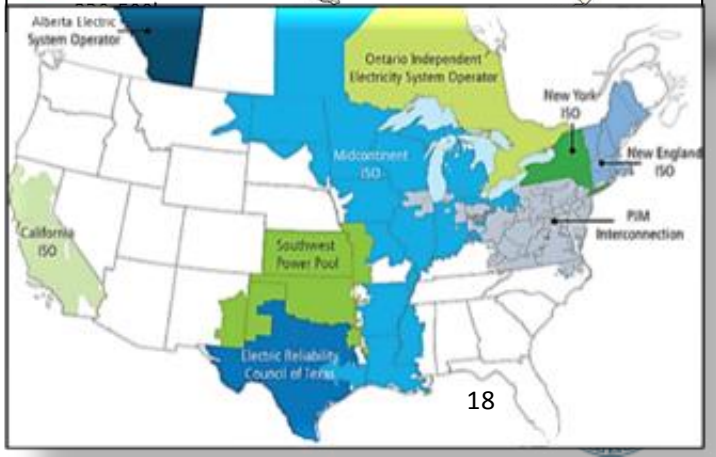
NERC Regional Entities and Balancing Authorities



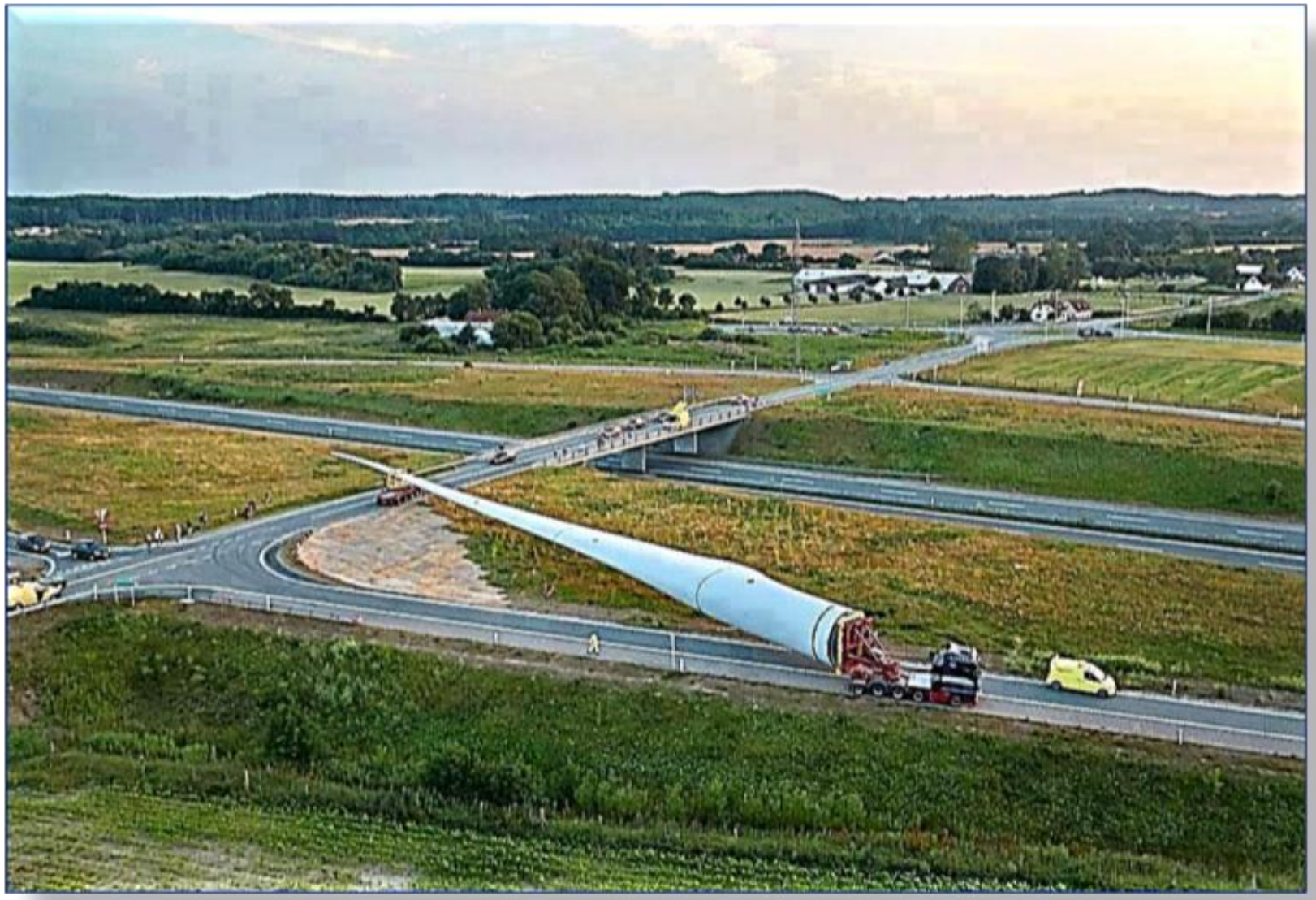
Federally Regulated Power Lines



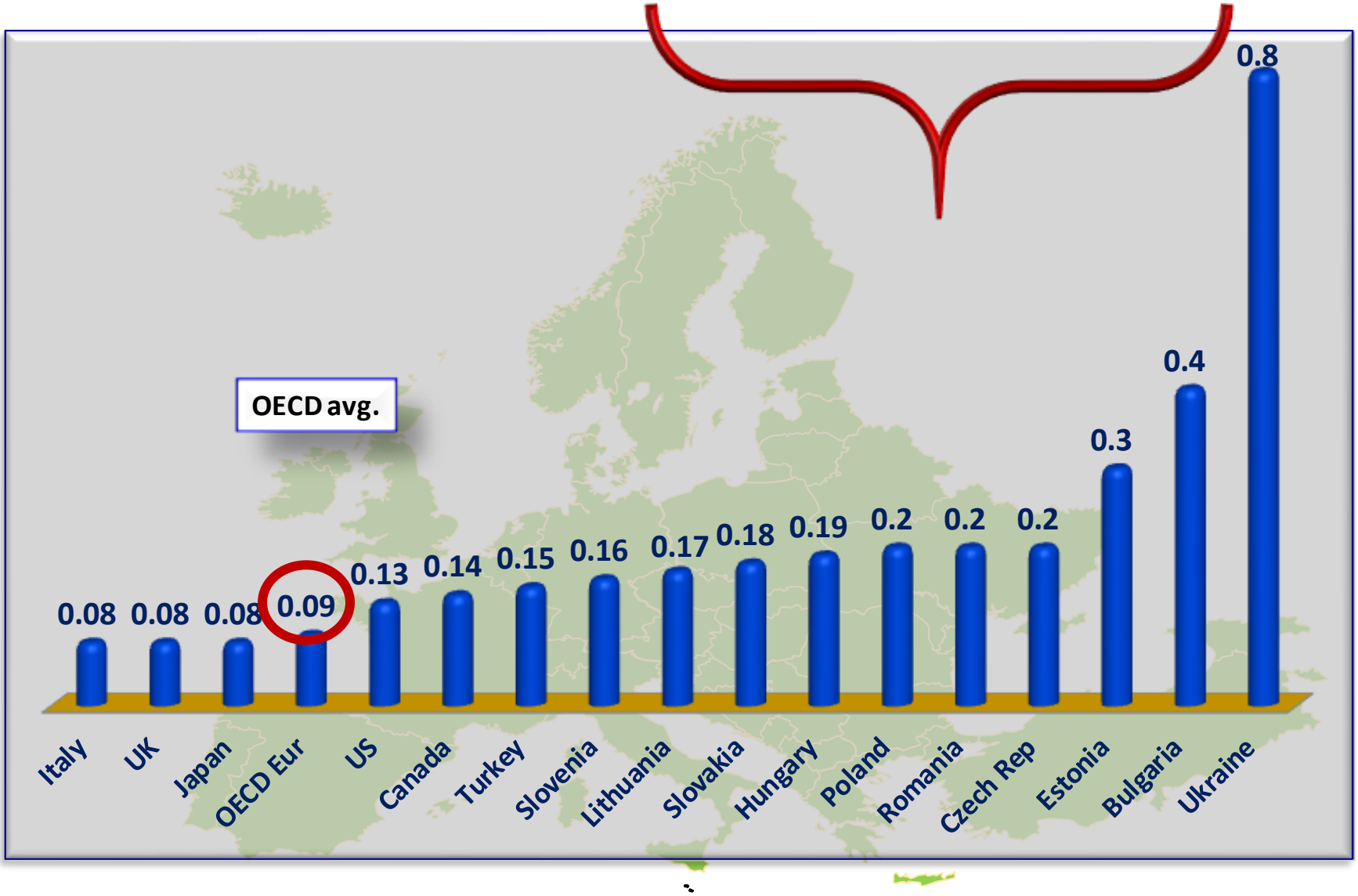
Regional Transmission Organizations (RTO)/ Independent System Operators (ISO)



Transporting Clean Energy Components on Shared Infrastructure



Lowering Energy Intensity Can Enhance Energy Security

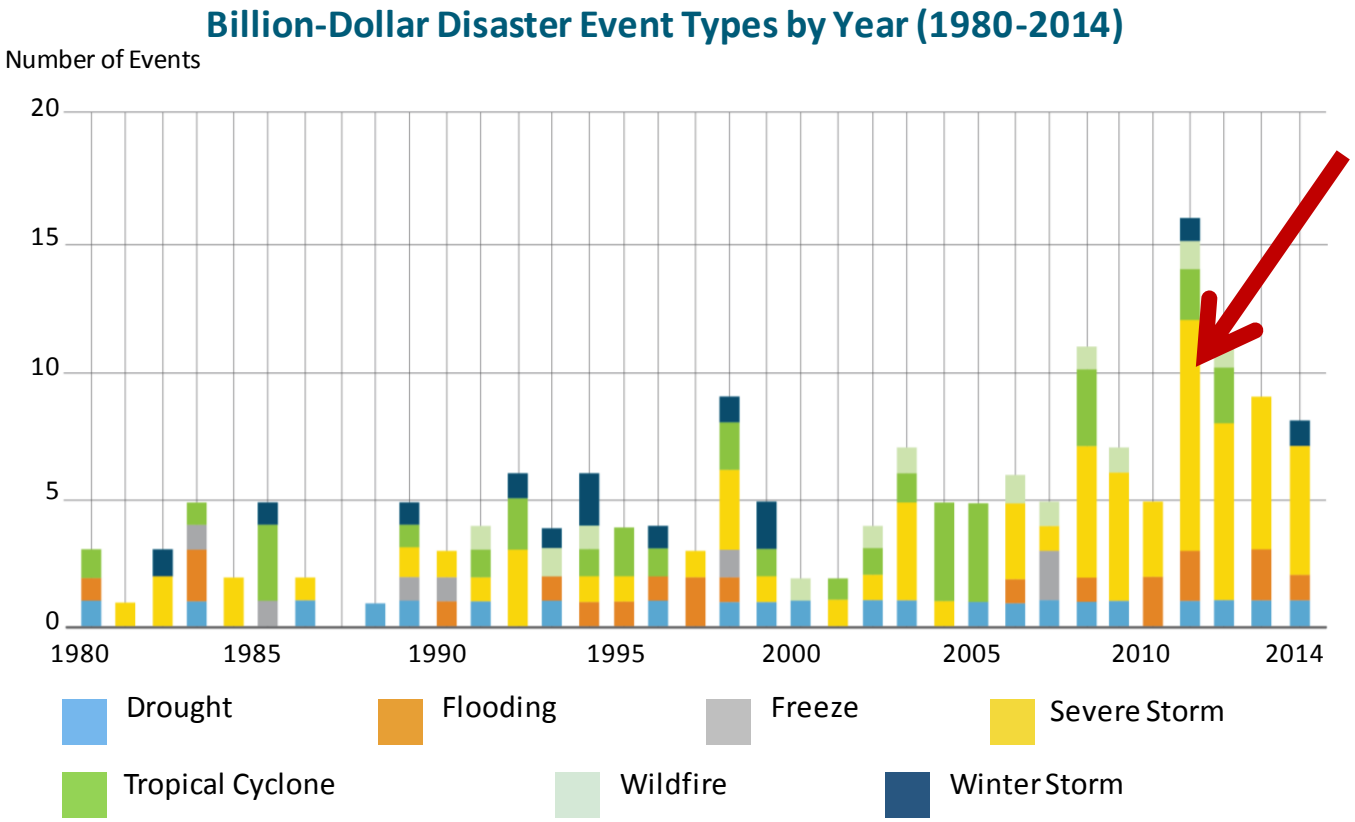


Intensity: 2012, USD base, toe/thousand, intensity numbers are rounded

Source: IEA

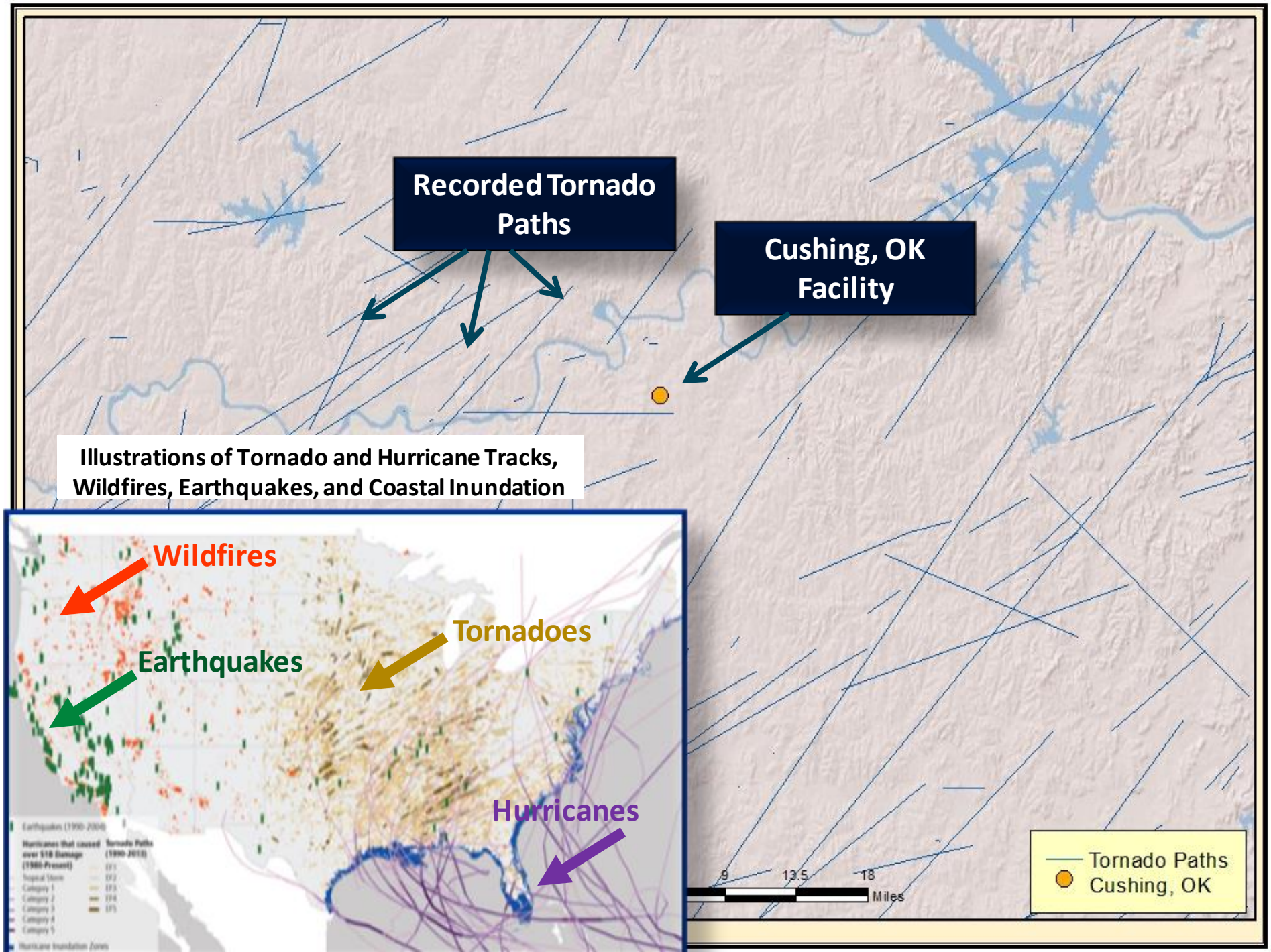
Improving energy systems resilience by promoting infrastructure modernization and supply and demand policies that help withstand systemic shocks.

Increasingly Costly Disruptions fro Severe Weather Events



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


Recorded Tornado Paths
Cushing, OK Facility
Illustrations of Tornado and Hurricane Tracks, Wildfires, Earthquakes, and Coastal Inundation
Wildfires
Earthquakes
Tornadoes
Hurricanes
9
13.5
18
Miles
Tornado Paths
Cushing, OK

Regional Fuel Resiliency Studies

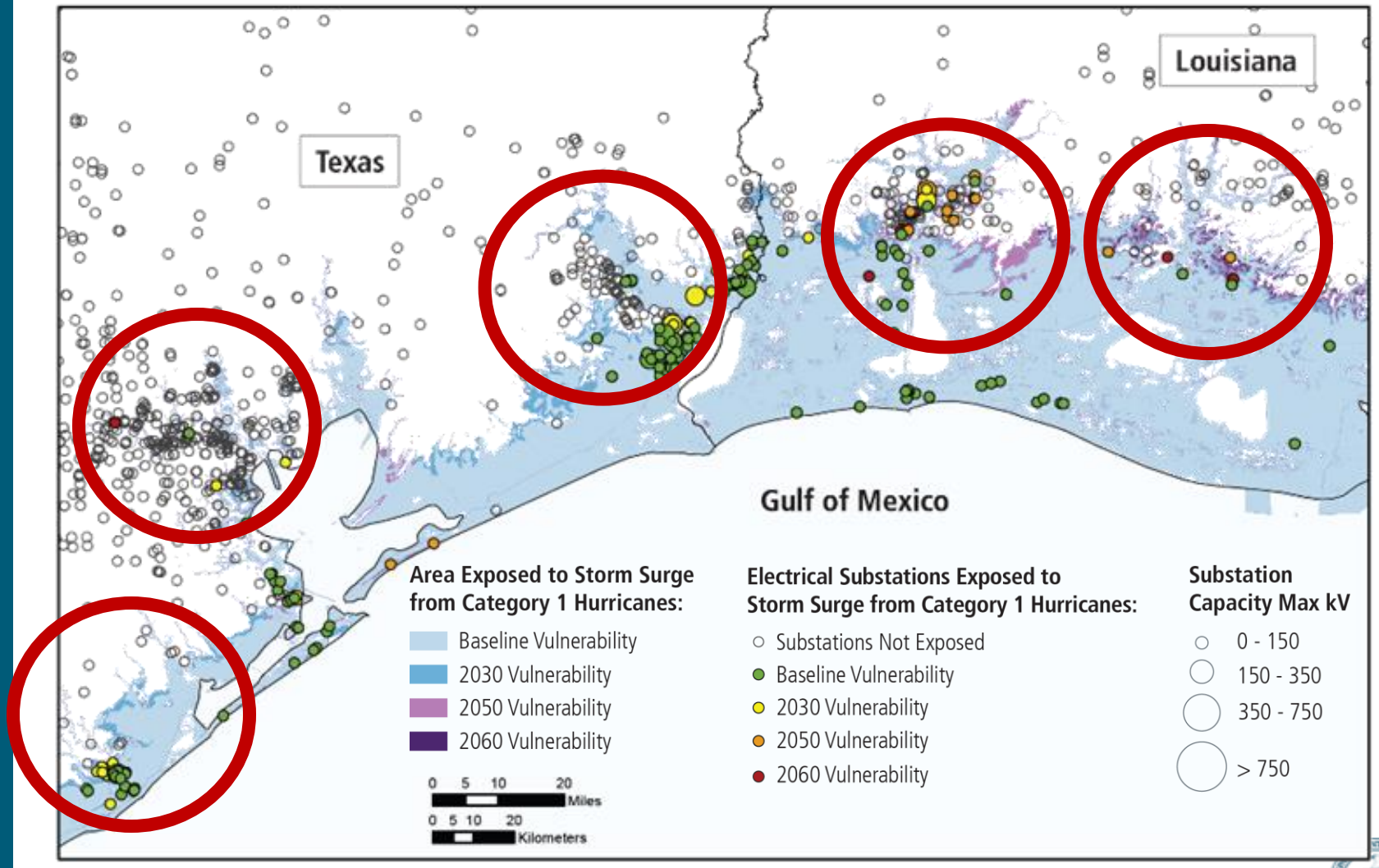
Far West. Increasingly depends on receiving shipments by water from other regions and from ports within region, including Alaska. Not well-connected to other PADDs by pipeline, receive s an increasing amount of its oil by rail. Susceptible to earthquakes and wildfires.

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.

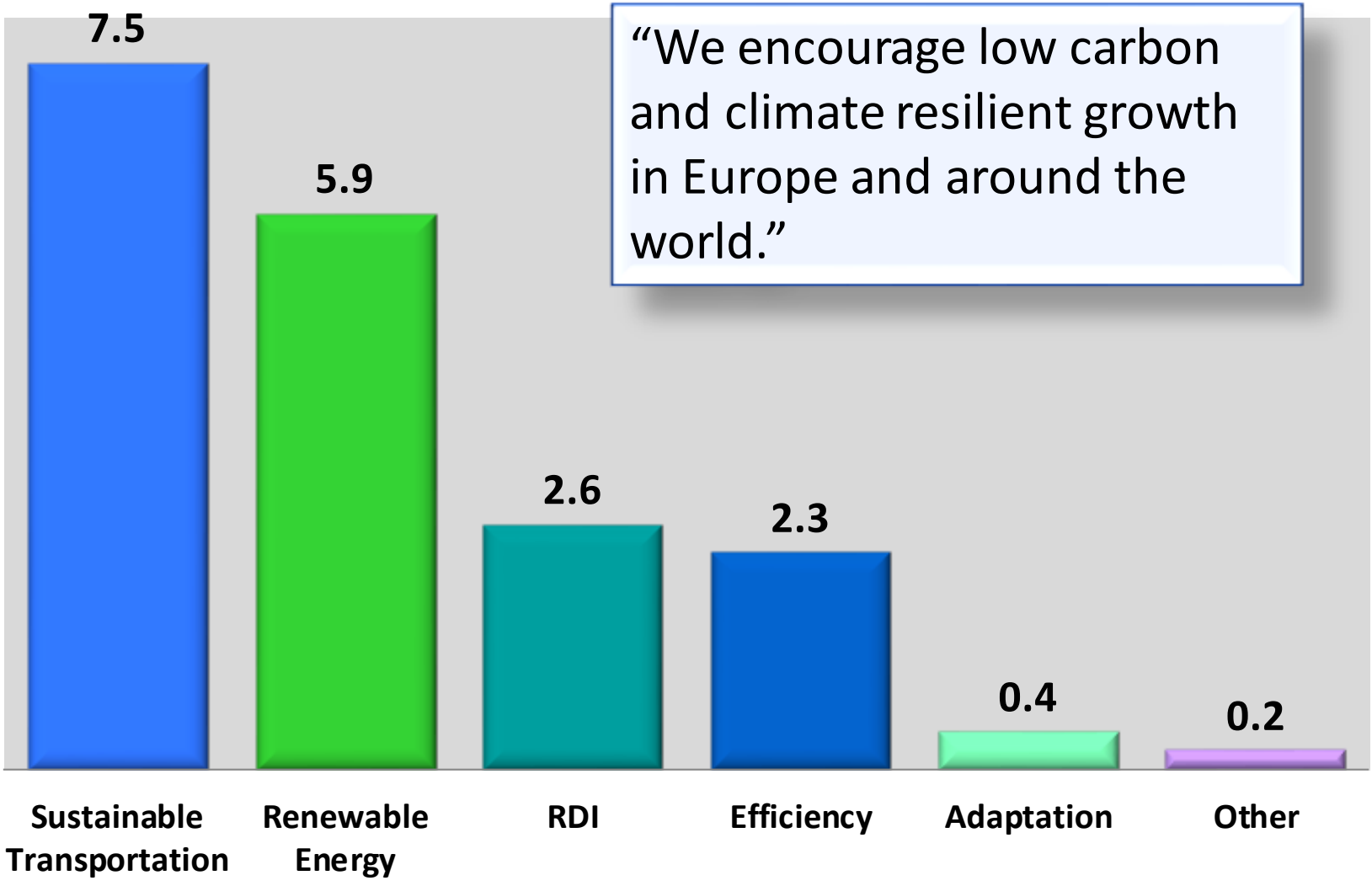
Vulnerabilities and Disruptions

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

Climate and Resiliency Spending, European Investment Bank, 2014



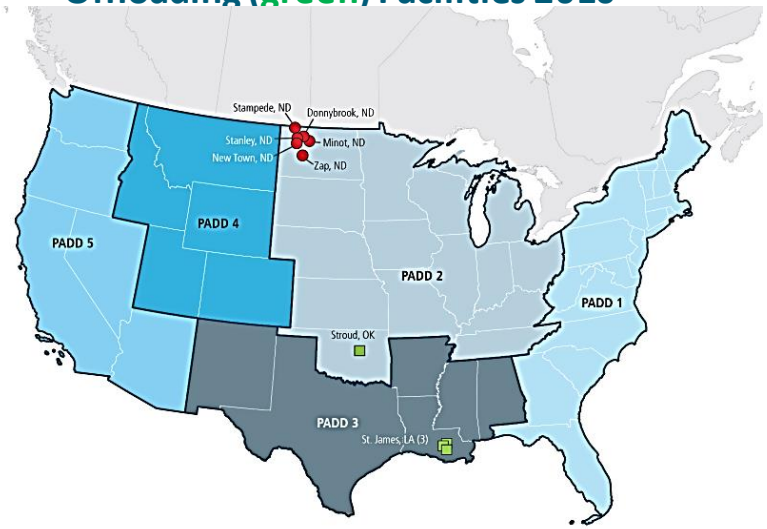
"We encourage low carbon and climate resilient growth in Europe and around the world."

Source: EIB Website

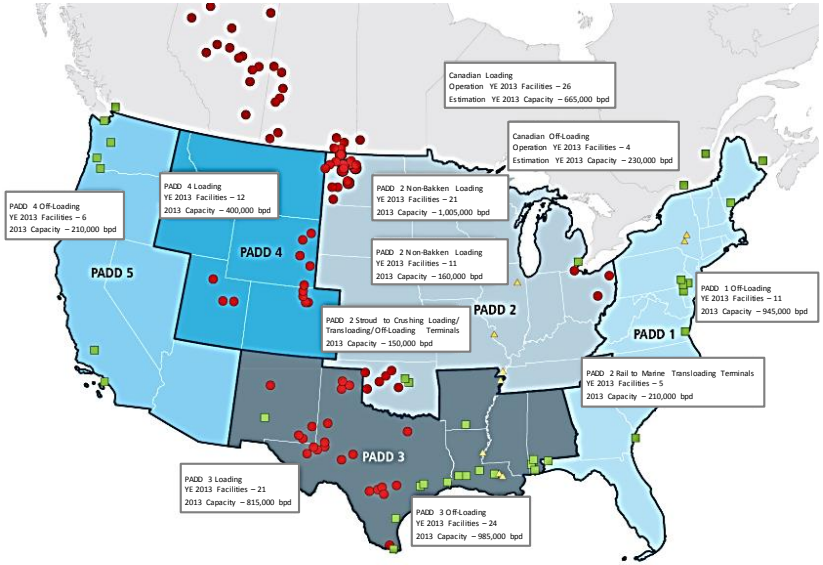
Putting in place emergency response systems, including reserves and fuel substitution for importing countries, in case of major energy disruptions.

Rapidly Changing Supply/Infrastructure Geography

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



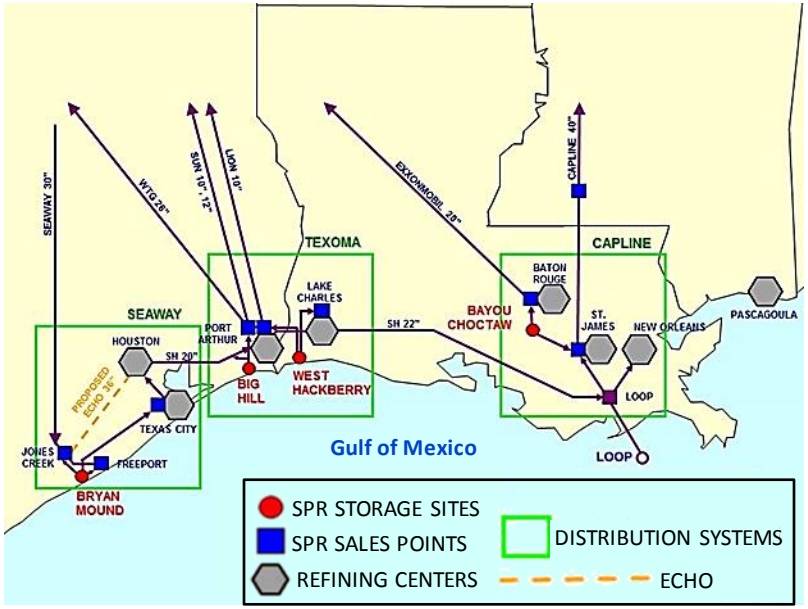
Crude Oil by Train Loading (red) and Offloading (green) Facilities 2013



- 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.

Modernizing the Strategic Petroleum Reserve (SPR)

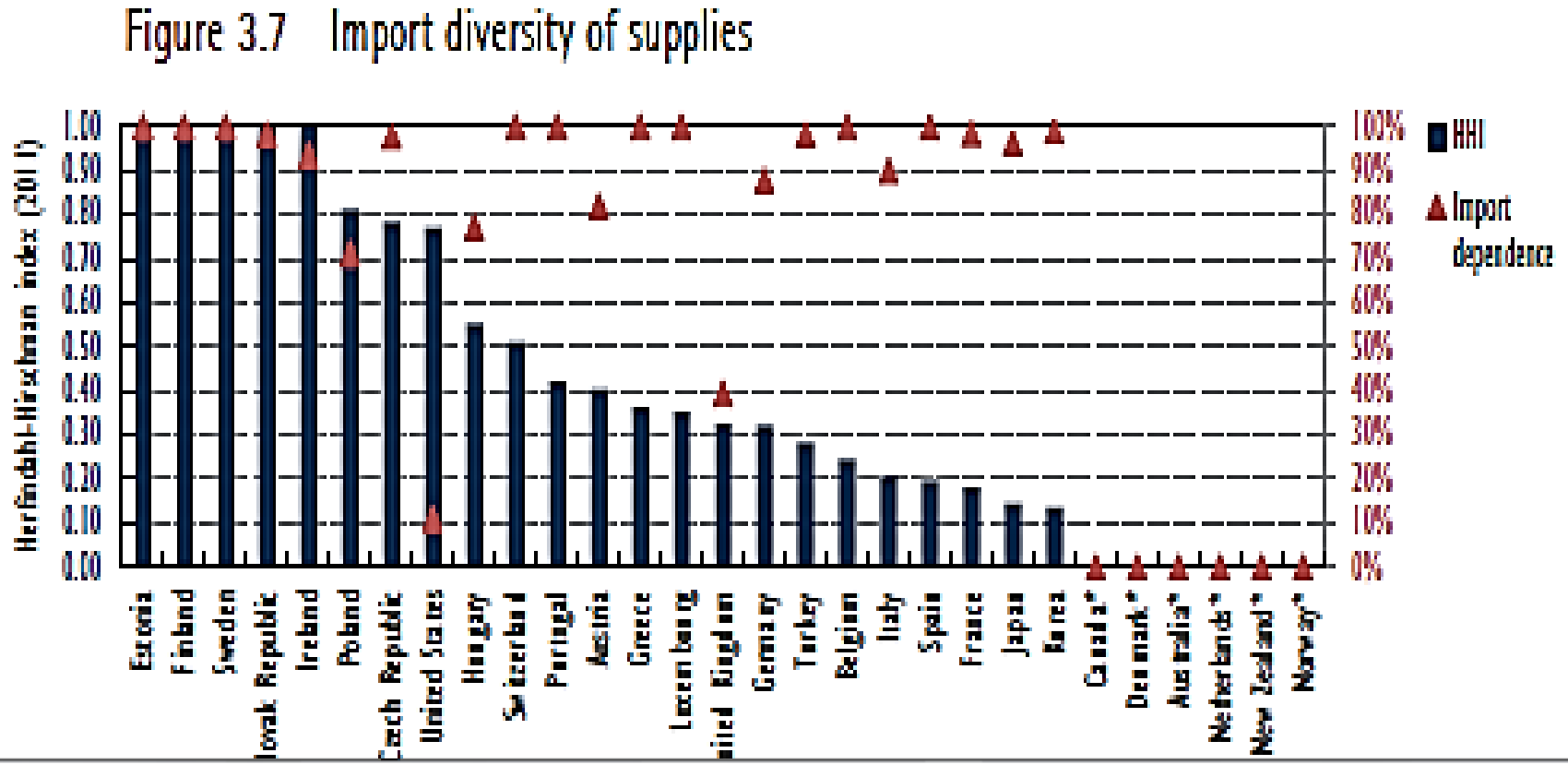


SPR Infrastructure in the Gulf of Mexico region

Selected SPR Findings

- The SPR is 40 years old
- Design drawdown rate of the SPR: 4.4 million barrels per day
- The SPR was designed to respond to oil embargoes -- to move oil from south to north, and to inland refineries
- Today, the SPR's value is to displace imports to the U.S. in the event of a global supply disruption, thereby lowering world oil prices and reducing economic harm to the US and its allies
- Congestion in the Gulf of Mexico is significant, which could limit the effectiveness of future SPR releases. Additional marine capability is needed to effectively distribute SPR crude.

Import Diversity of Gas Supplies: European Energy Security Vulnerability



Energy markets have changed substantially since the creation of the international Energy Agency...Natural gas is playing an ever-growing role in the energy balances of IEA countries, making gas security a key element in energy security. Unlike the case of oil however, there is no framework for taking collective action in response to a natural gas disruption and IEA countries do not have the equivalent treaty requirements [for gas]..."

Source: IEA 2014, Hirfendahl, Hirschmann