U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

The Emerging Role of Energy as the Key to Economic Prosperity for the United States.

Presented by:
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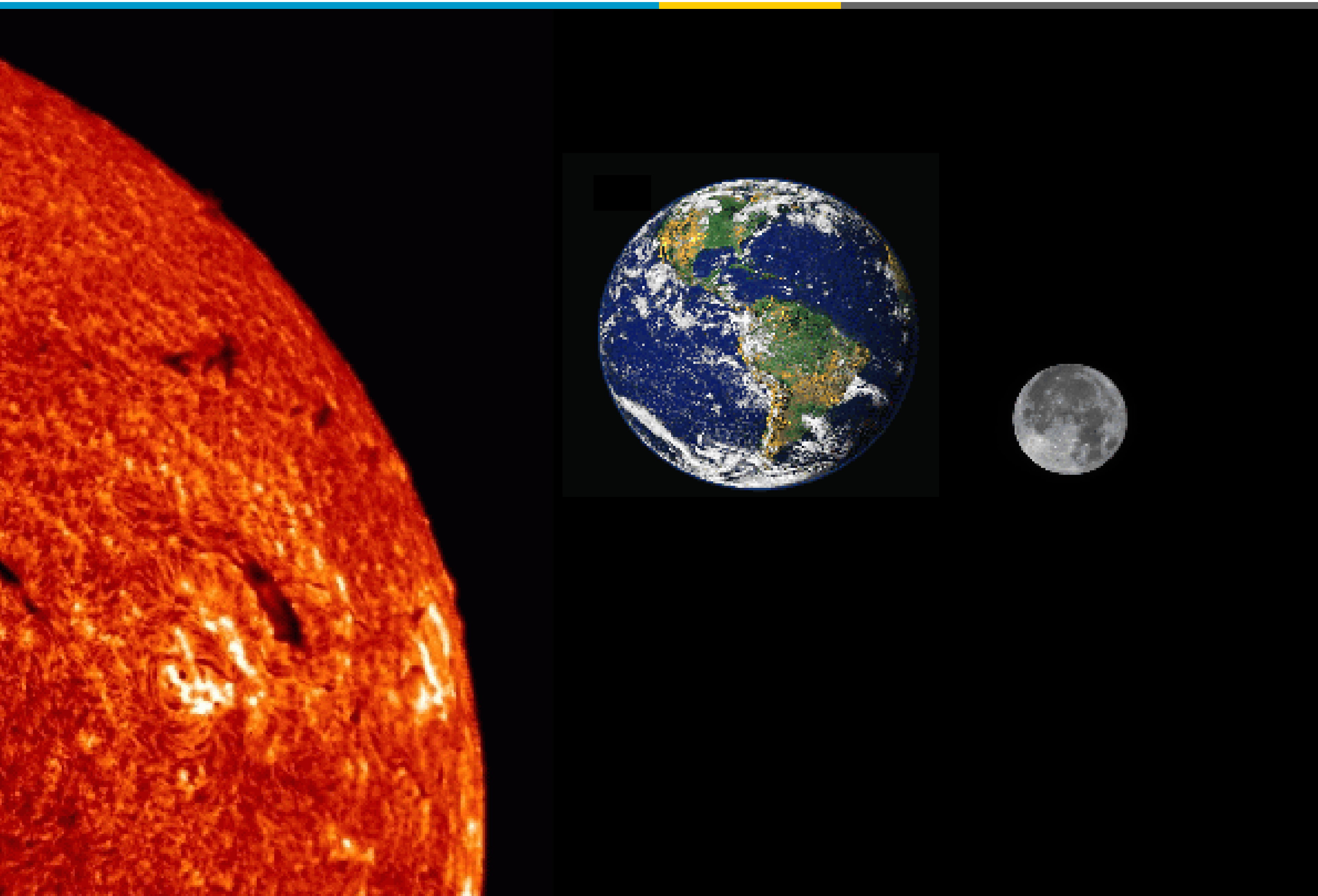
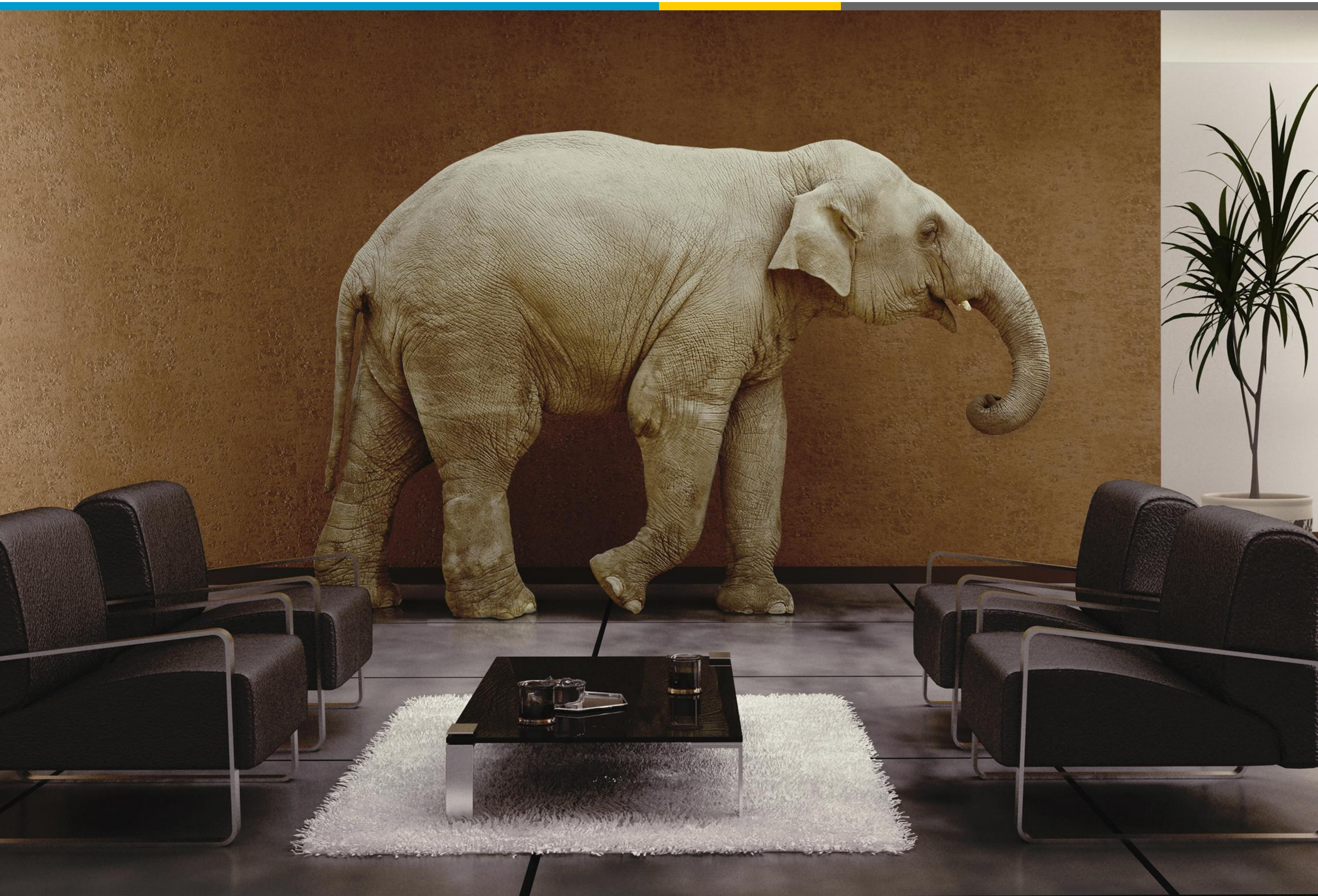
United States Department of Energy

Presented in Clearwater, Florida
January, 2012

The Irony of it All



Electricity is the Elephant in the Room



The Smart Grid Steps into the Real World

No matter how efficient or renewable the technologies may be, their potential will not be realized without a major overhaul of the electric grid.

This has heightened the interest of policymakers, consumers, and businesses alike and have focused them on enacting smart grid concepts as part of an effort to reinvigorate America's economy through energy and environmental sustainability.

Energy and environmental sustainability means our economic systems must be fueled by energy systems that are

Reliable

Efficient

Secure

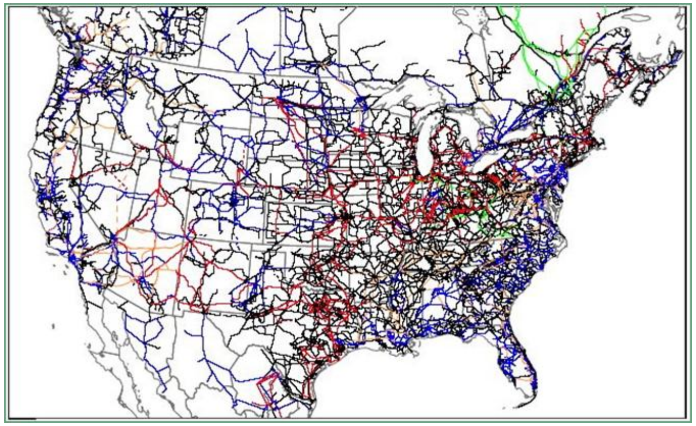
Clean

"To meet the energy challenge and create a 21st century energy economy, we need a 21st century electric grid"

DOE Secretary Chu
September 2009

This is the digital age and our electric grid is using electro-mechanics from the 1960s and 70s rather than microprocessors. Approximately 70 percent of the transformers and transmission lines are 25 years old; and 60 percent of the circuit breakers are 30 or more years old.
We are relaying on a 19th century system from the days of Edison and Westinghouse that uses 20th century equipment in an effort to keep up with a 21st century economy. The power grid was not designed to support the extensive coordination of generation, transmission and distribution that is called for today and it faces stresses and challenges that are creating drivers for the modernization and restructuring of the grid to accommodate the needs and requirements of a 21st century economy.

The Electric Grid - A Complex System



Physically

Not holistically designed, evolved incrementally in response to local load growth. Today:

- 30,000 Transmission paths + 180,000 miles of transmission line
- 14,000 Transmission substations
- Distribution grid connects these substations with over 100 million loads—residential, industrial, and commercial customers

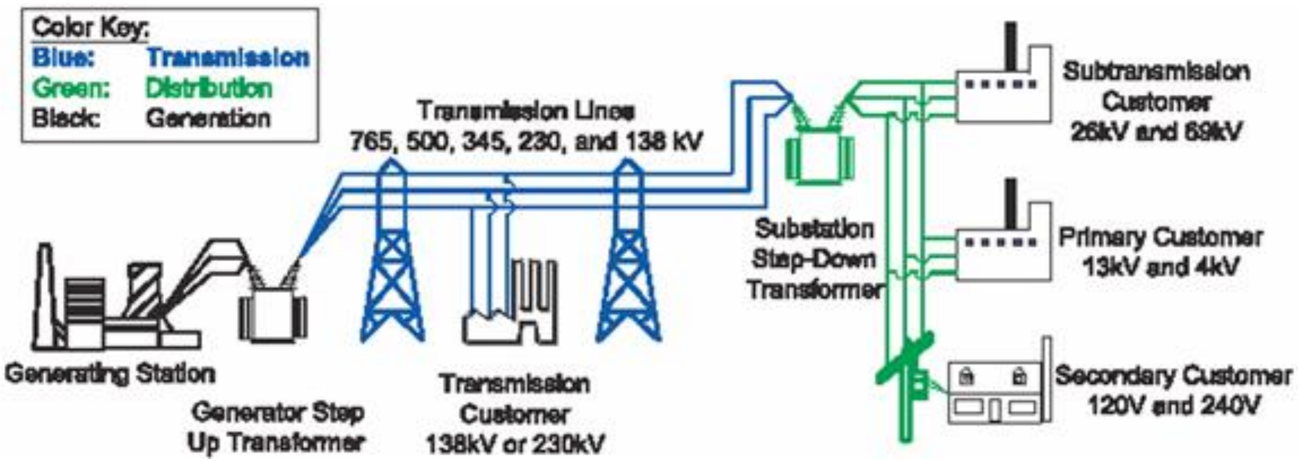
Diverse industry

- 3,170 traditional electric utilities
- 239 investor-owned, 2,009 publicly owned, 912 consumer-owned rural cooperatives, and 10 federal electric utilities

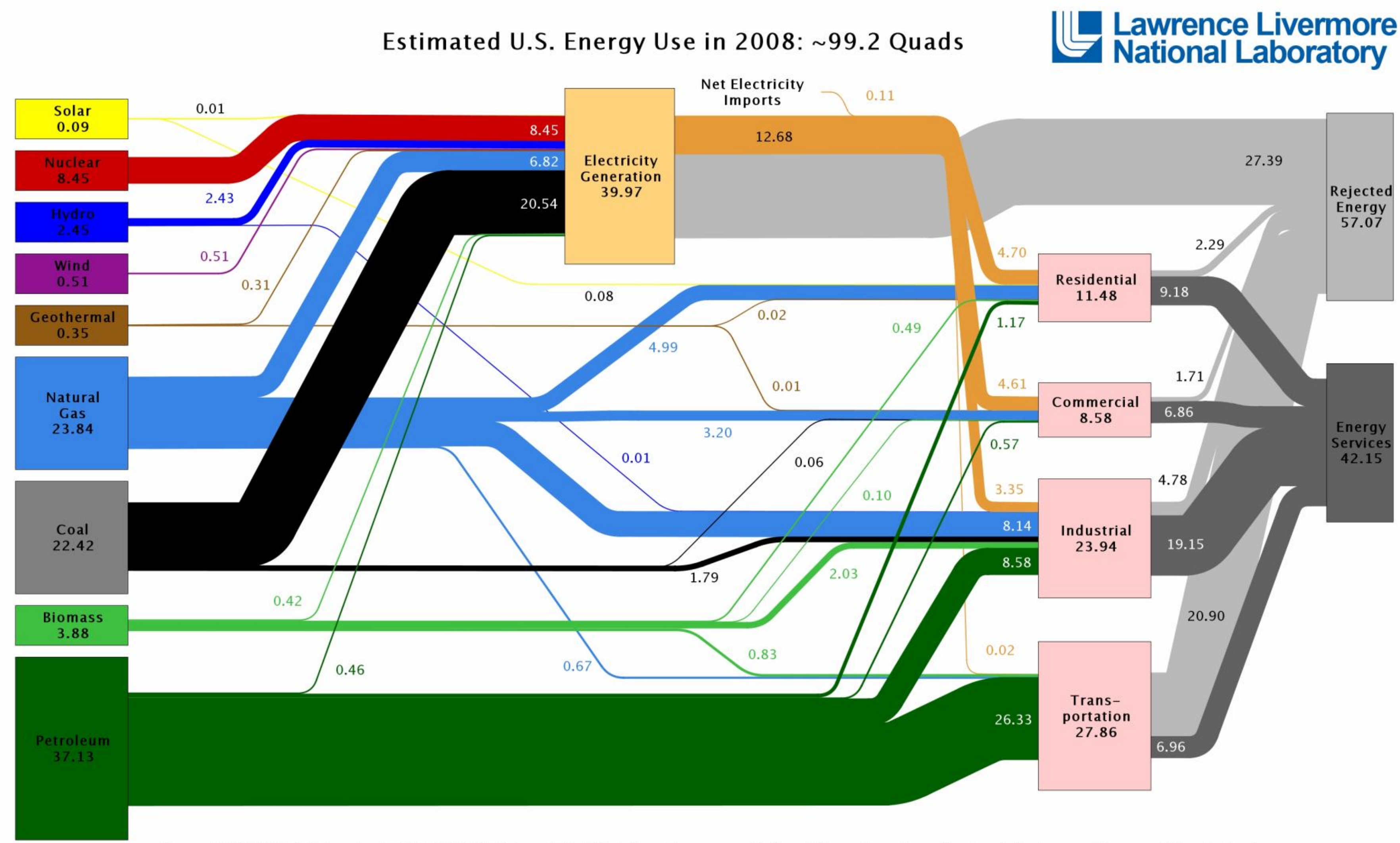
Technically

- Electricity flows within three major interconnections along paths of lowest impedance (at the speed of light); yet grid is operated in a decentralized manner by over 140 control areas
- Demand is semi-uncontrolled—smart grid technologies provide opportunity for dynamic, real-time balancing of demand and supply (demand response)
- Ultimate "just-in-time" production process

Dumb Grid - One Way Street to a Dead End



Energy Use and Waste 2008



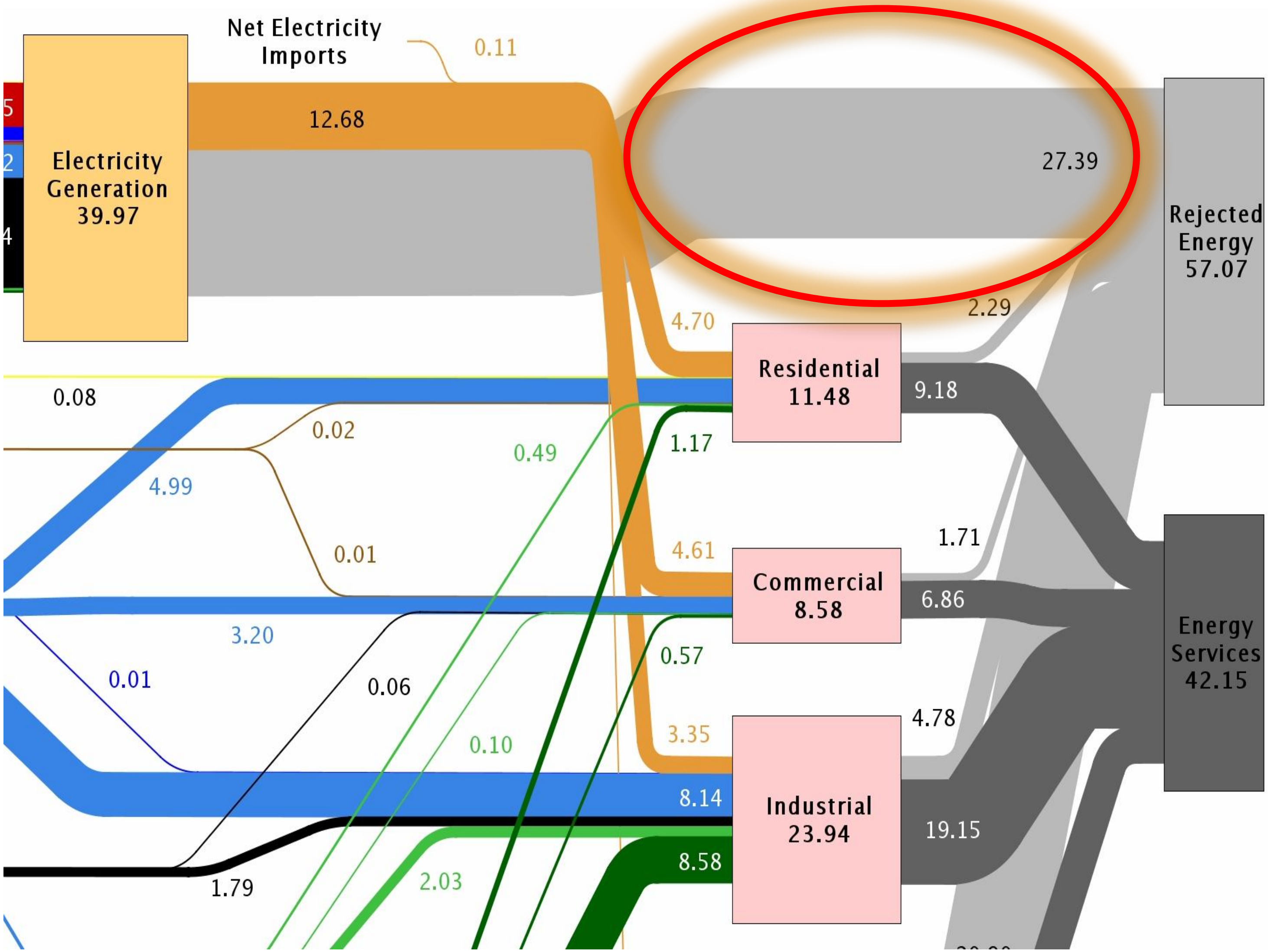
Source: LLNL 2009. Data is based on DOE/EIA-0384(2008), June 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports flows for non-thermal resources (i.e., hydro, wind and solar) in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 80% for the residential, commercial and industrial sectors, and as 25% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

2/3 of Electric Generation is Lost Through Inefficiencies

39.97% of all fuel sources to go electric generation.

27.39 % of the fuel sources that go to electric generation is wasted. Another way to look at is nearly ***75% of the power that goes to electric generation is wasted.*** This is power that is never used!

8.78 % of waste comes from buildings & industry combined – that is only a THIRD of what is wasted by unused electric power.



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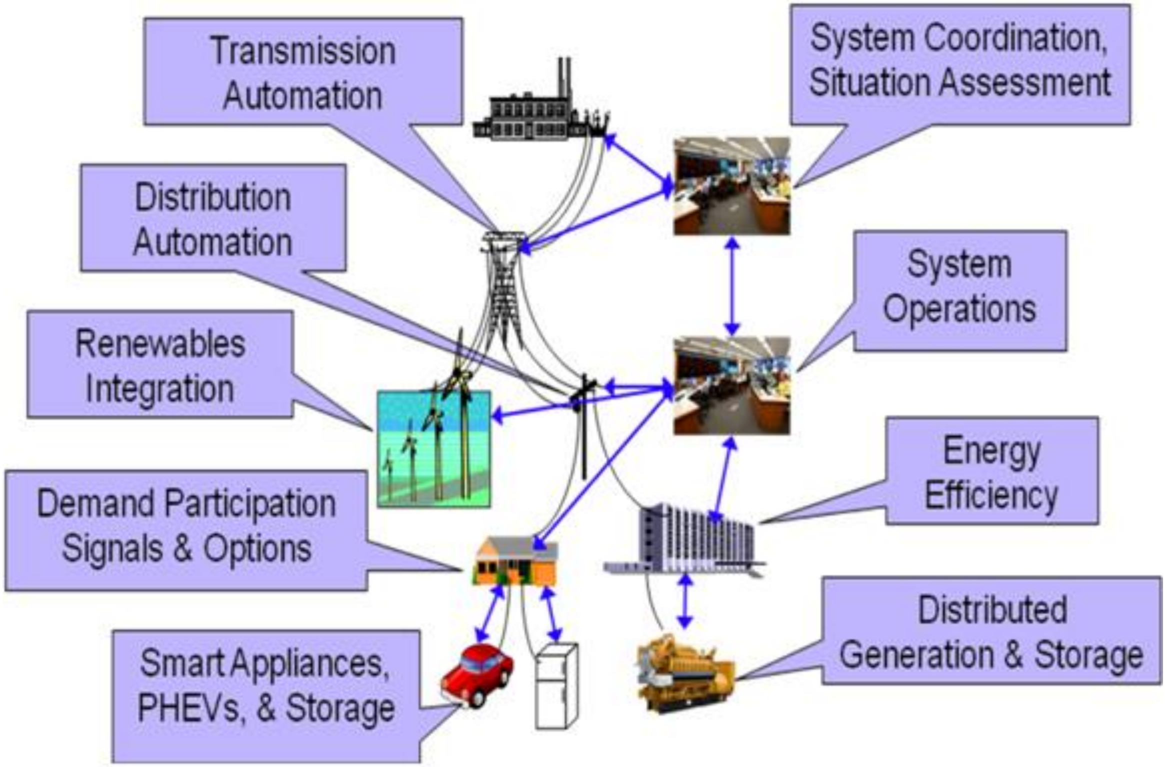
Key Trends and Drivers for a 2030 US Electric Grid

2008		2030
3.1% renewable (non-hydro) 6.0% hydro 19.6% nuclear 21.4% natural gas 48.2% coal 1.7% oil and other	Electricity Supply Mix	• More wind and solar power • More distributed generation and storage • Same or more natural gas-fired generation • Same or more nuclear power • Less coal
• 3,733 million MWh • 752,740 MW non-coincident peak demand	Demand Requirements	• 20% more electricity consumption • 25% higher peak demand • Adoption of plug-in electric vehicles • Widespread consumer participation in dynamic pricing
• 140 control areas • “Gridlocked” siting and permitting • Interoperability requirements	Complexity of the Grid	• Volumes of phasor and smart meter data to manage and use • $ billions investment in automated T&D systems • Interoperable and integrated power generation, delivery, and end-use
• Aging infrastructure and workforce • Cyber security awareness • Infrastructure interdependence	Vulnerabilities of Energy Infrastructure	• More digitalization and controls • Increased interdependencies • Built-in cyber security protections against mounting threats

Smart Grid – Utilizing Digital Technologies to Enhance the Reliability, Security, and Efficiency of the Electric System



Smart Grid Characteristics

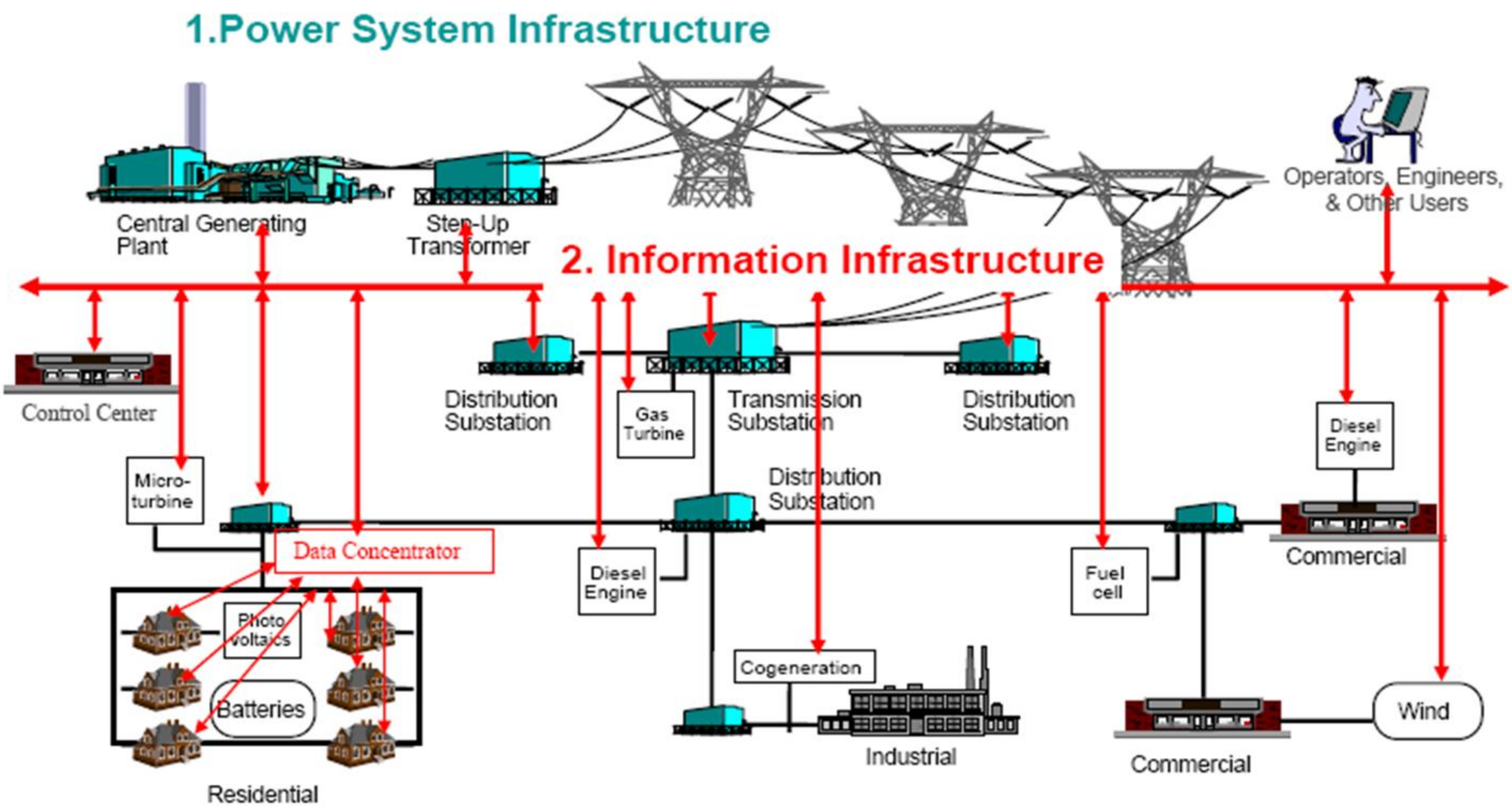
- Enable active participation by consumers
- Accommodate all generation and storage options
- Enable new products, services, and markets
- Provide power quality for the digital economy
- Optimize asset utilization and operate efficiently
- Anticipate & respond to system disturbances
- Operate resiliently against attack and natural disaster

What effect will the 21st century electronomics have on our lives?

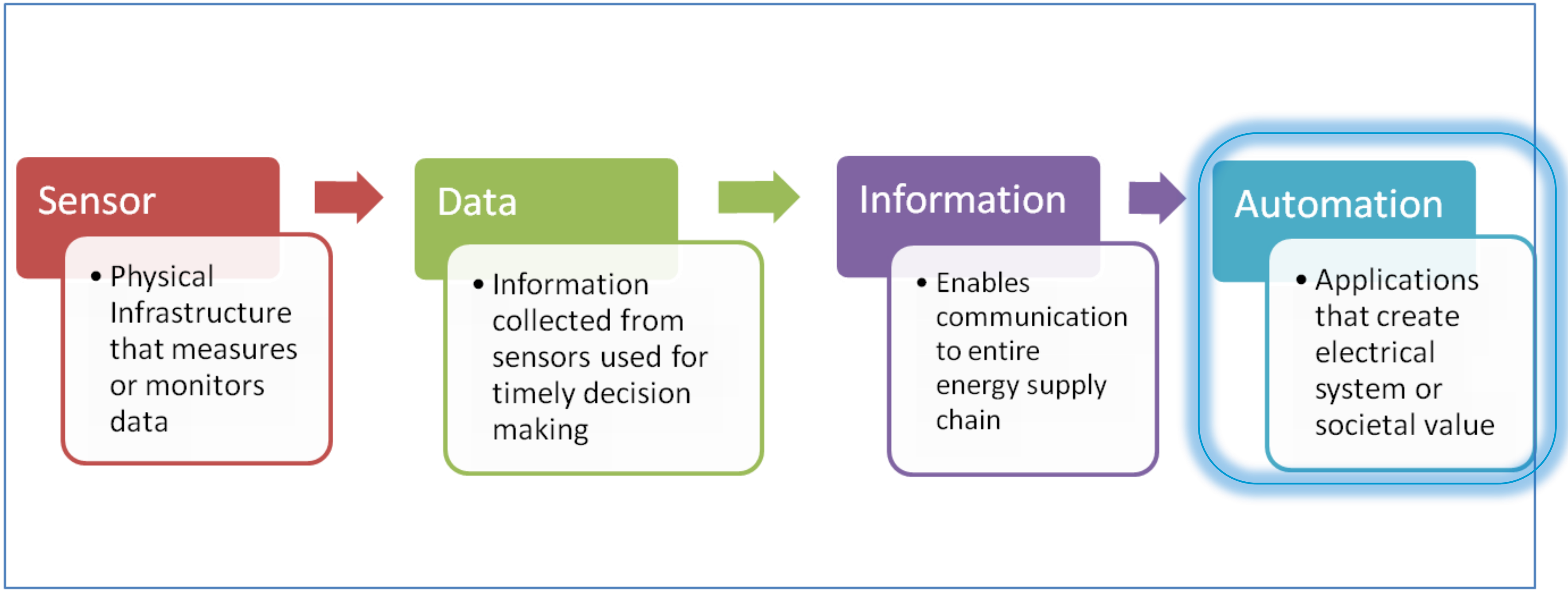
There are five sweeping trends that smart grid implementation will help usher in:

1. a brand new interstate and inter-country highway system for electricity
2. a transformed transportation sector based on electric power
3. community-scale micro-electricity grids versus the centralized command-and-control electricity distribution we’ve known for a century
4. customized choice for consumers when it comes to electric consumption
5. smart infrastructure based on the digital revolution

Electric "Smart Grid" – Electricity + Information



However Information is Not Enough – What Makes a Grid "Smart", Anyway?



One of the best ways to understand the new electric smart grid of the 21st century is by analyzing the rapidly emerging electricity economy, or electronomics, as it is sometimes called. Electricity has the potential to, and must be structured to, add value to the economy. To do so, ***the smart grid infrastructure must enable new forms of commerce***. Structured properly, it will help spawn new fortunes ***on a vast scale - a scale we haven't seen in the United States for many decades or more.*** They will be the new Microsofts, Apples, and Googles.

Electric Transportation

Plug-in electric vehicles (PEVs) are now on the market throughout the United States. However, while PEV's do lessen the reliance on crude oil and do not create emissions when operated in full electric mode, they do rely on power plants to charge their batteries, and conventional fossil-fueled power plants emit pollution.

To maximize PEV value by making them as clean as possible, they need to be charged in the very early morning, when power demand is at its lowest, wind power is typically at its peak, and rates are more attractive.

The smart grid's infrastructure will enable the efficient use of PEVs ***by interacting with a vehicle to automatically charge it at the most optimal time, and turn off when the vehicle has been completely charged.***

Enabling a Charging Infrastructure for PEVs

One of the key factors for acceptance of PEVs in the marketplace will be the availability of charging For now, ***many municipalities and private companies offer free charges to PEV owners as an incentive for purchasing these clean vehicles. However,*** as PEVs gain market penetration, this benefit is likely to come to an end, and charging ***station owners will be seeking a convenient way to charge PEV owners for their "fill-ups."***

Smart Grid technologies offer a potential solution to this problem by ***identifying PEVs to the charging station when they are plugged in, and automatically billing the electricity used to the owner's account.*** The technology will not only simplify transactions for the charging station owners, but also allow PEV owners to charge up without the need for cash or a credit card.

Infrastructure has always been the key to prosperity in the United States - whether it's been the transcontinental railroad, the interstate highway system, the telephone, or the internet - ***and building a smart electricity grid for the 21st century is no different*** than these historic infrastructures.

Our goal should be one vast, interconnected, intelligent system that is monitored and controlled end to end - all the way down to billions of individual devices.

Building out ***a smart grid will allow us to remain competitive in a*** rapidly evolving ***electricity economy***. Right now, we're falling behind.

Many of the most exciting and aggressive ***smart grid initiatives are coming from overseas***.

- Much of the Middle East is using its oil money to create a state-of-the-art smart grid along with sustainable cities.
- Europe spends 10x than that of the U.S. on smart grid research.
- China is leading the world in high-voltage transmission and next-generation grid efforts.

If we want to keep pace we must invest our resources and ourselves into this effort!

This New Economy Will Enable…

interdependence not isolation

efficiency not waste

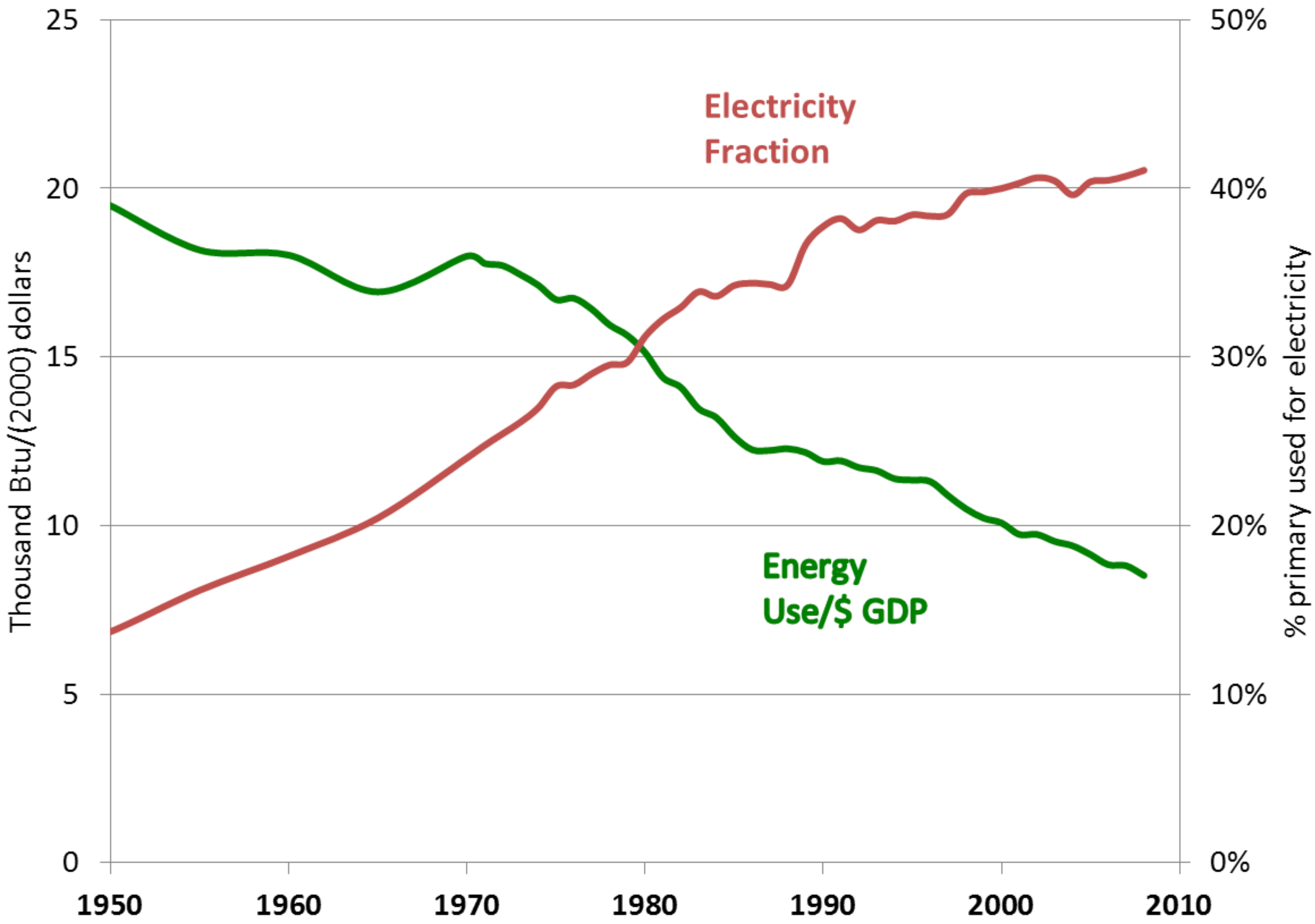
sustainability not vulnerability

and a power system focused on the future, not mired in the past.

As individuals and businesses have become dependent on electronic devices for information exchange and commerce, ***the use of electricity as an energy source has grown relative to fuels, currently representing 40% of overall energy consumption in the US.***

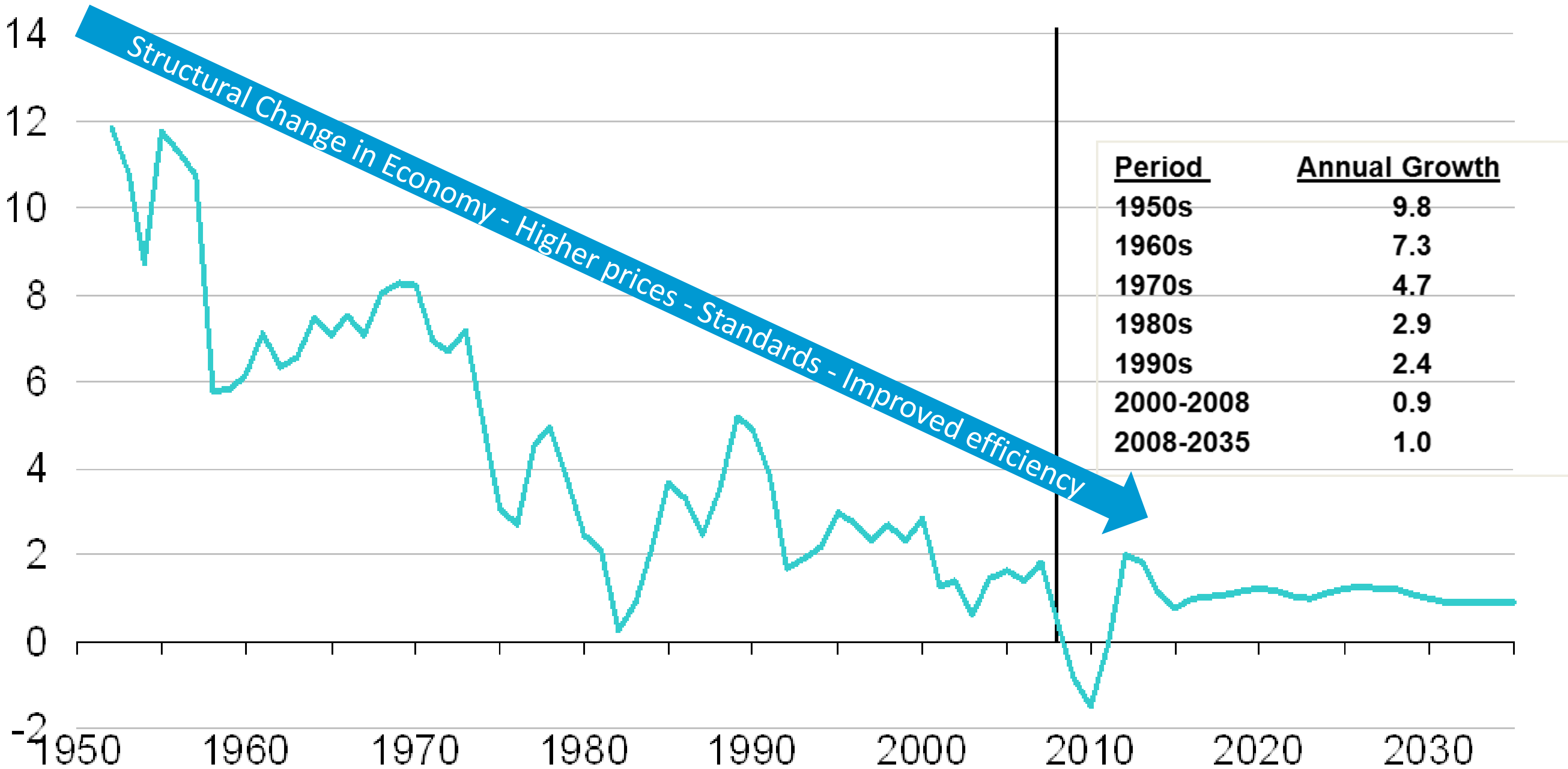
The importance of electricity as a driver of economic growth can be gauged from the fact that ***electricity sales trend with the growth of the GDP more closely than other energy sources***.

But the U.S. Has a High (and Growing) Dependence on Electricity



Growth Rate in Electricity Flattens

3-year rolling average percent growth

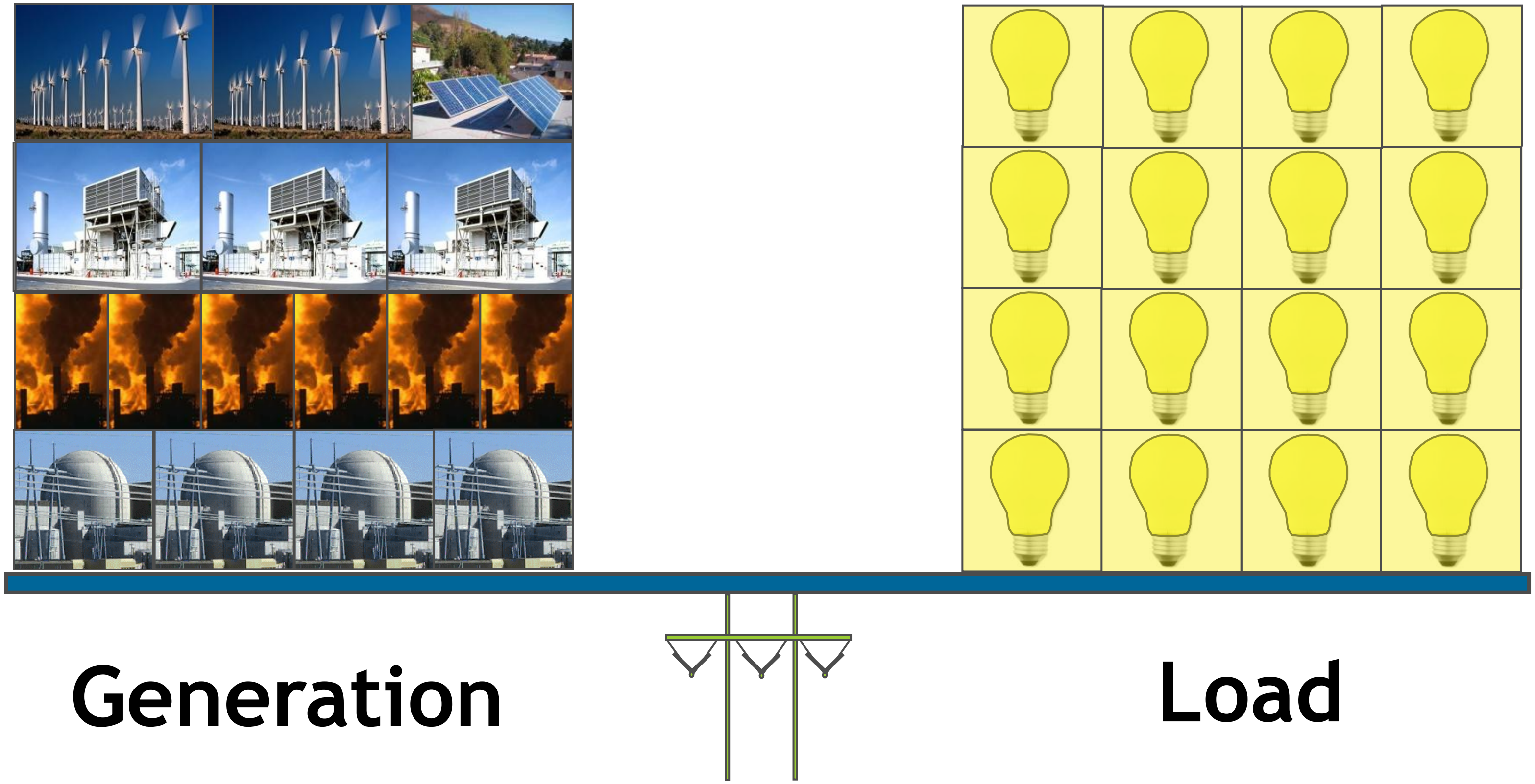


Period	Annual Growth
1950s	9.8
1960s	7.3
1970s	4.7
1980s	2.9
1990s	2.4
2000-2008	0.9
2008-2035	1.0

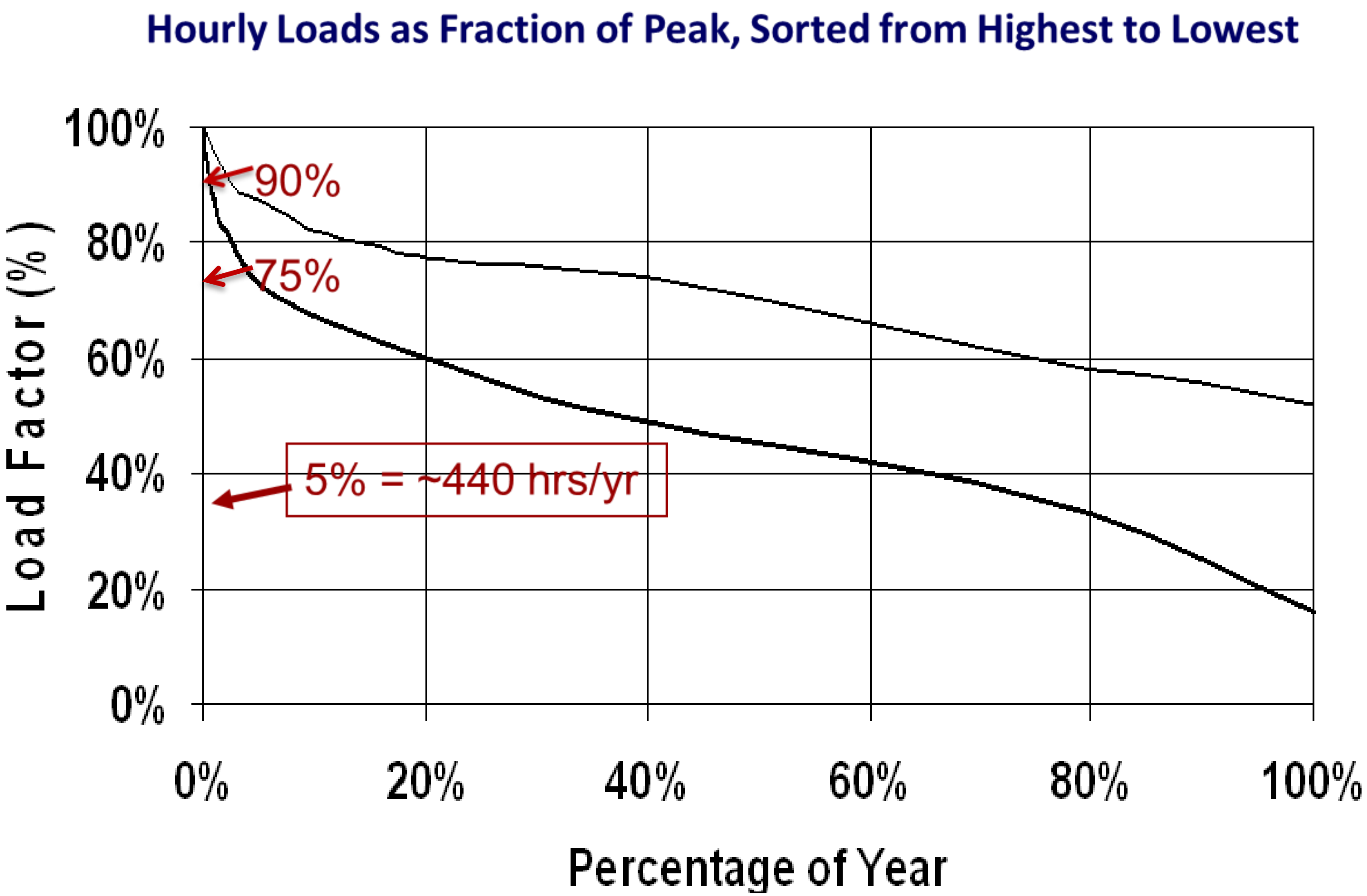
Challenge - Balancing Generation and Load at the Same (Instantaneously)

Objective

Less Variability - More Predictability

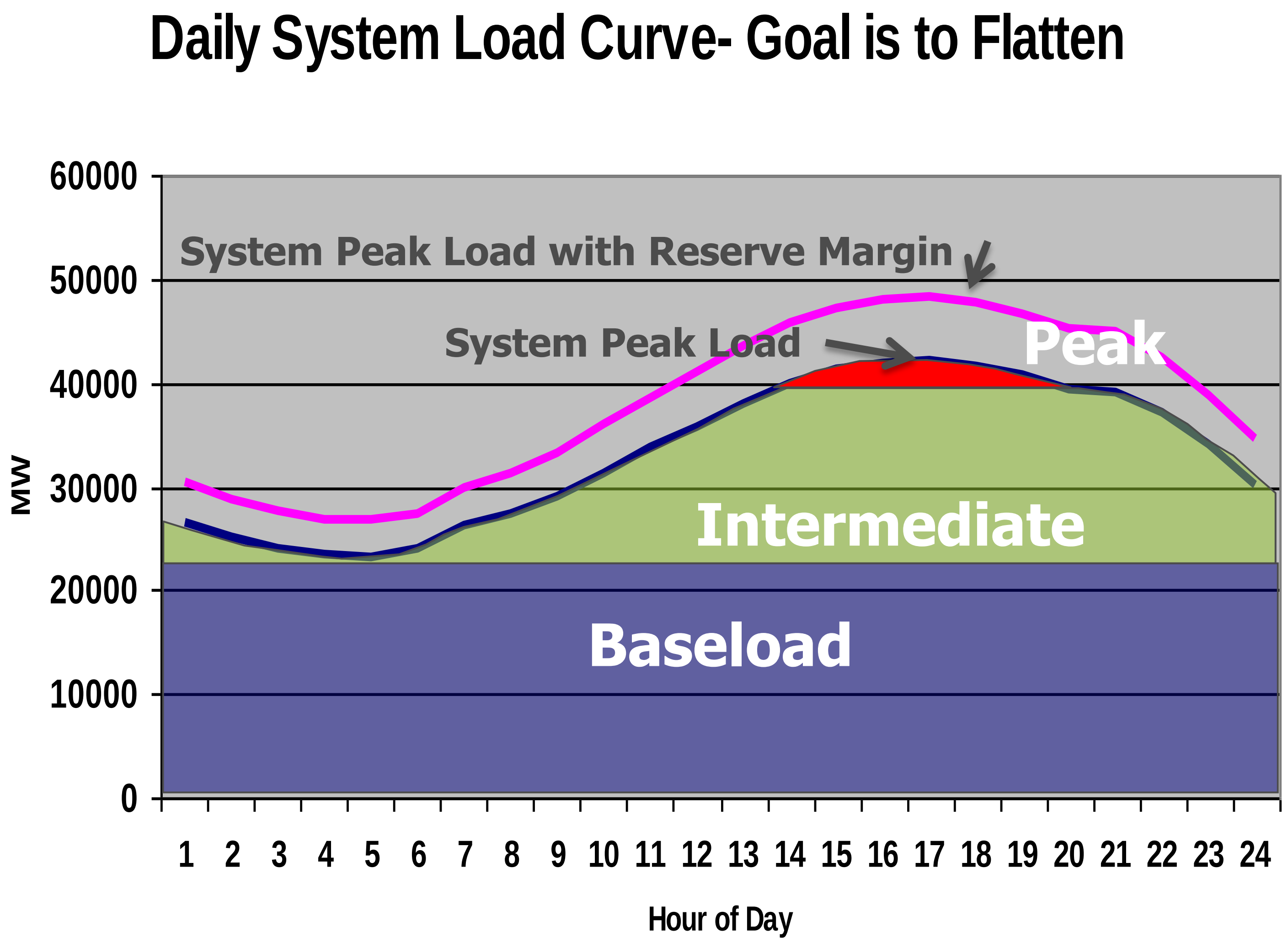


Smart Grid Technologies Can Reduce Peak Load and Defer T&D Investments

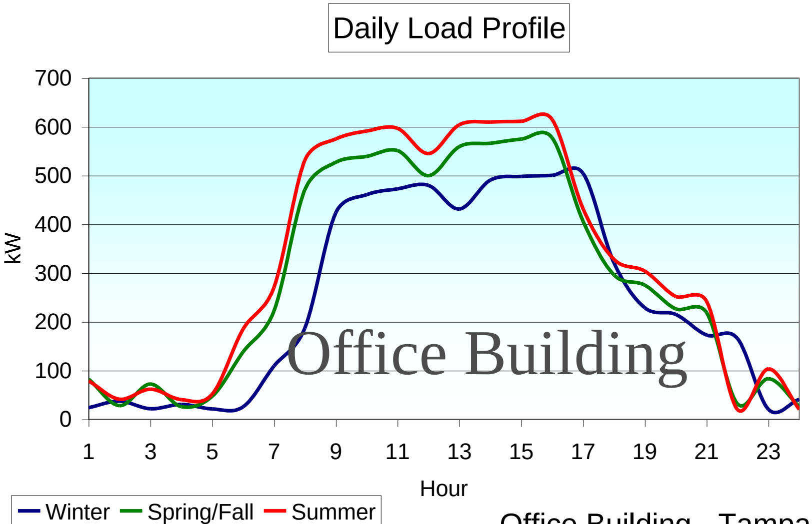


>25% of distribution and >10% of generation assets are needed less than 5% of the time ($100s of billions of investments)

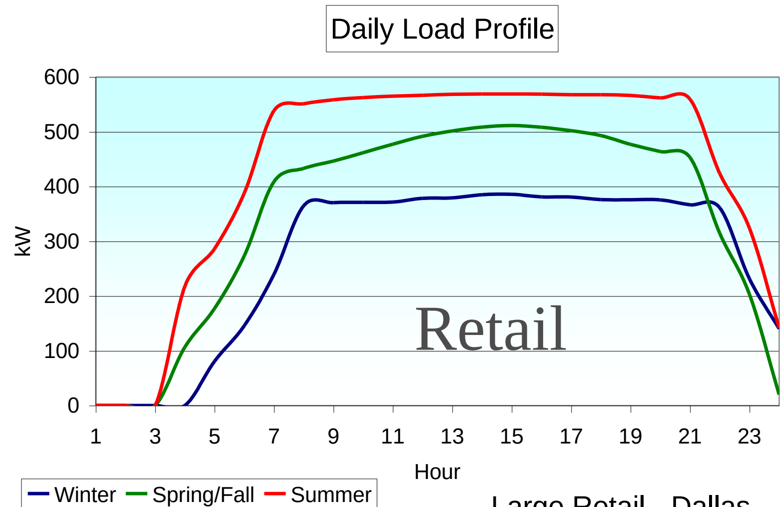
Daily System Load Curve – Demand Response Will Assist in Flattening the Curves



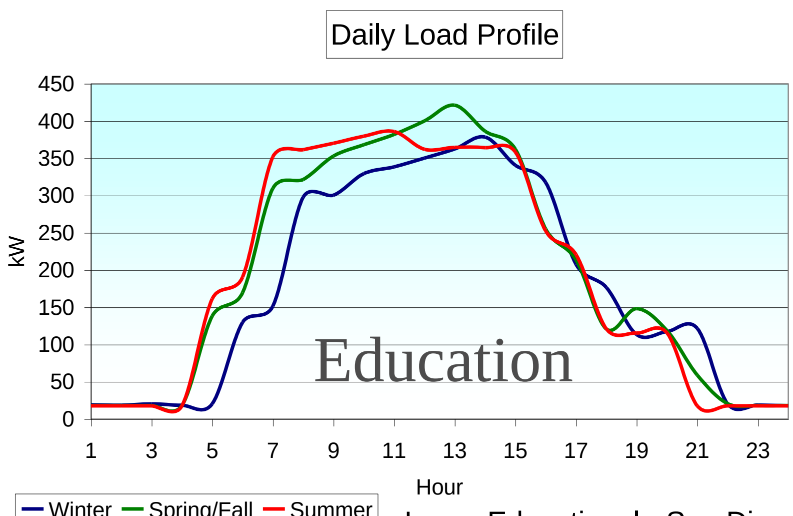
Other Load Profiles Showing High Variables Requiring a Very Flexible, Scalable, and Elastic Grid



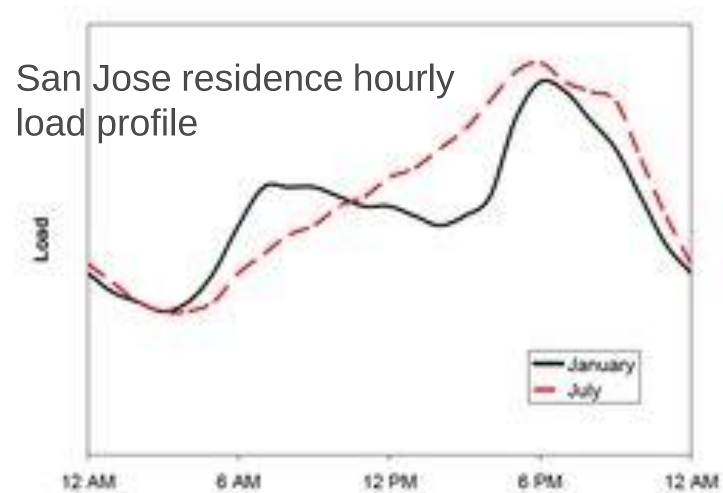
Office Building - Tampa



Large Retail - Dallas

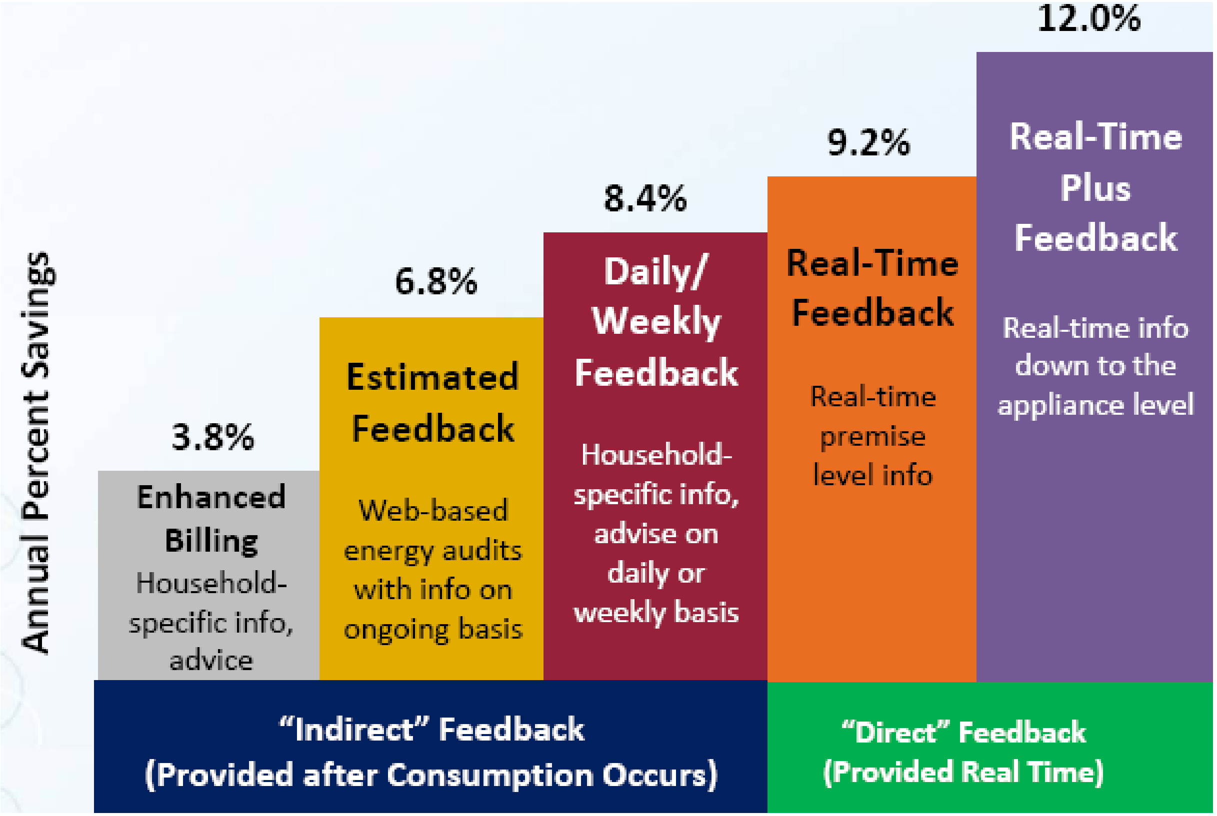


Large Educational - San Diego



Advanced Metering Will Impact Demand Cycles

Average Household Electricity Savings (4-12%) by Feedback Type



With persistent feedback there is persistent savings.

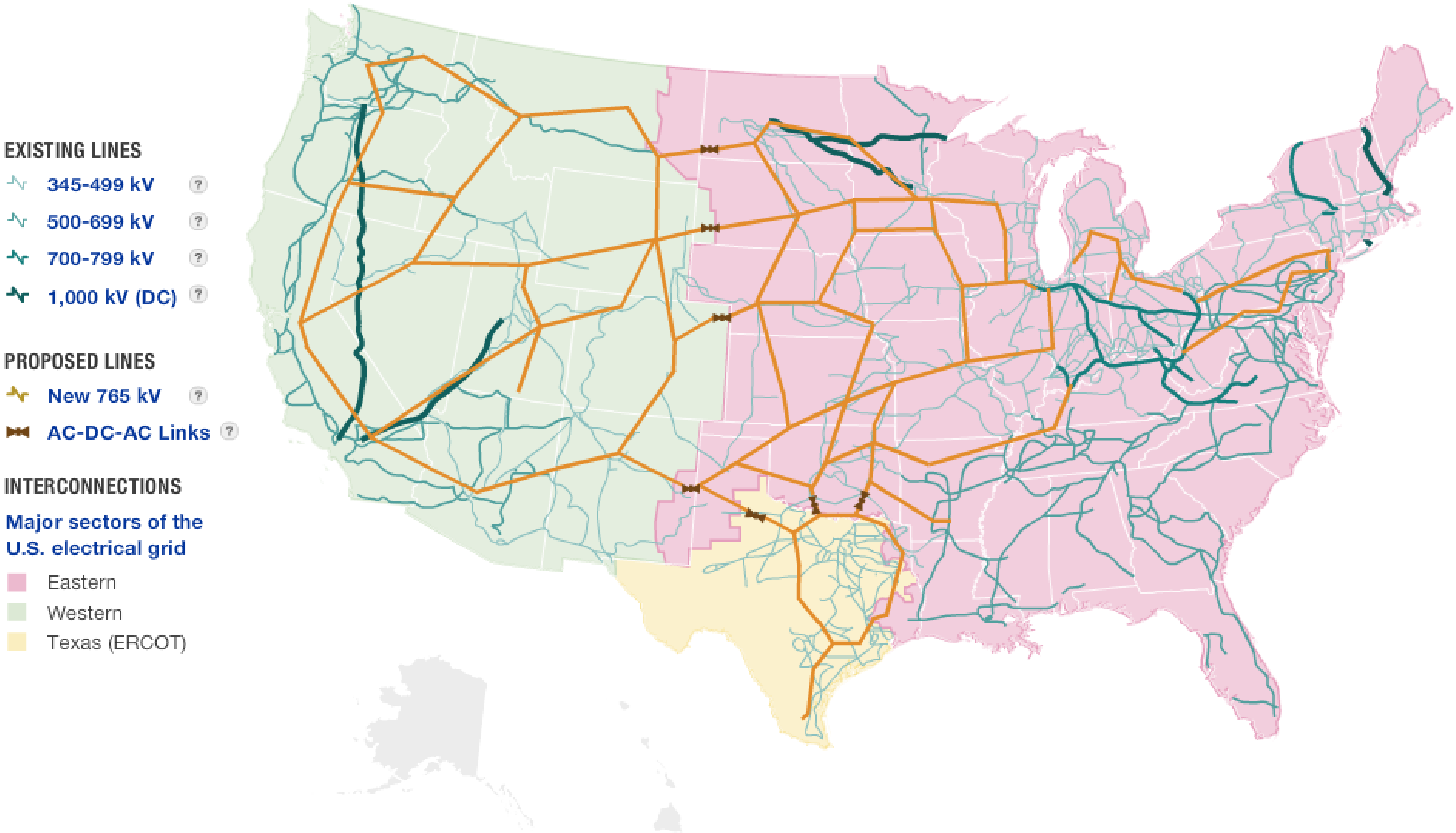
Advanced metering will not reduce cash flow and reduce profits. Quite the opposite. It is conservation, and ***it will work in tandem with grid efficiencies to reduce demand,*** thereby deferring investments or redirecting them to better technologies ***that will enhance the bottom line for energy providers and consumers alike.***

This does not mean demand will decrease, it will just lessen the severity of increased demand.

Demand <u>WILL</u> increase. As such, ***fossil fuels are not going away*** - at least not within our lifetime, or even our children's lifetime. However, it does mean that we must find avenues to provide for ***additional power beyond what fossil fuels are able to provide***.

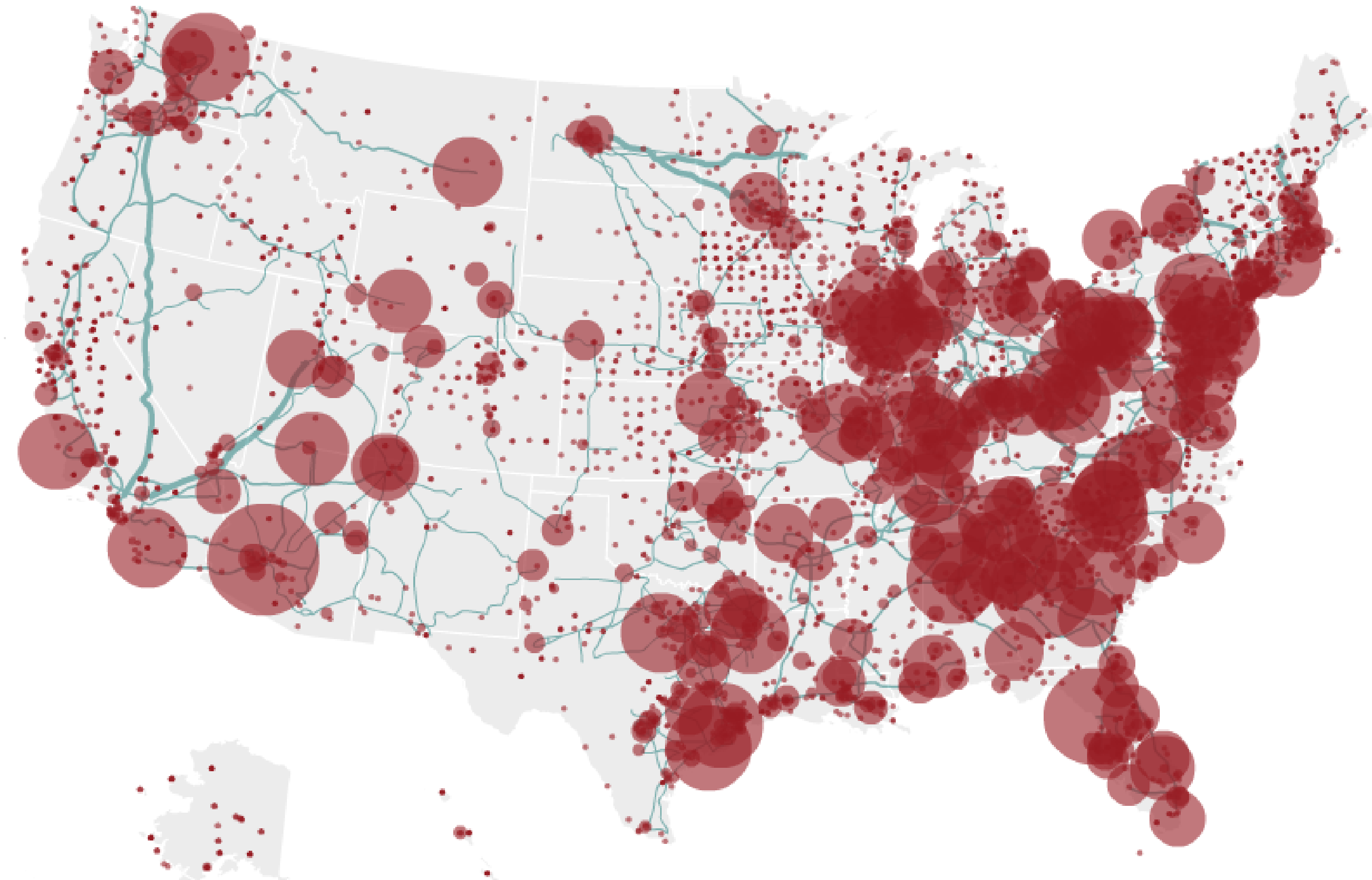
Our current grid was really developed for fossil fuels and flat generation. We must ***adjust the grid*** to be more flexible in order ***to seamlessly integrate variable power sources***.

The Power Grid System Does Not Tell the Whole Story



Source: American Electric Power, American Wind Energy Association, Center for American Progress, Department of Energy, Edison Electric Institute, Energy Information Administration, Electric Power Research Institute, Federal Energy Regulatory Commission, National Renewable Energy Laboratory, U.S. Environmental Protection Agency, Western Resource Advocates
Credit: Producer: Andrew Prince; Designer: Alyson Hurt; Editors: Avie Schneider and Vikki Valentine; Supervising Editors: Anne Gudenkauf and Quinn O'Toole; Additional Research: Jenny Gold; Database and GIS Analysis: Robert Benincasa

Current Power Plants and Main Power Arteries



EXISTING LINES

Existing electric power grid

NOTE: Data for this map comes from the U.S. EPA's eGRID database. Not all power-generating facilities in the U.S. are plotted on this map.

Source: American Electric Power, American Wind Energy Association, Center for American Progress, Department of Energy, Edison Electric Institute, Energy Information Administration, Electric Power Research Institute, Federal Energy Regulatory Commission, National Renewable Energy Laboratory, U.S. Environmental Protection Agency, Western Resource Advocates

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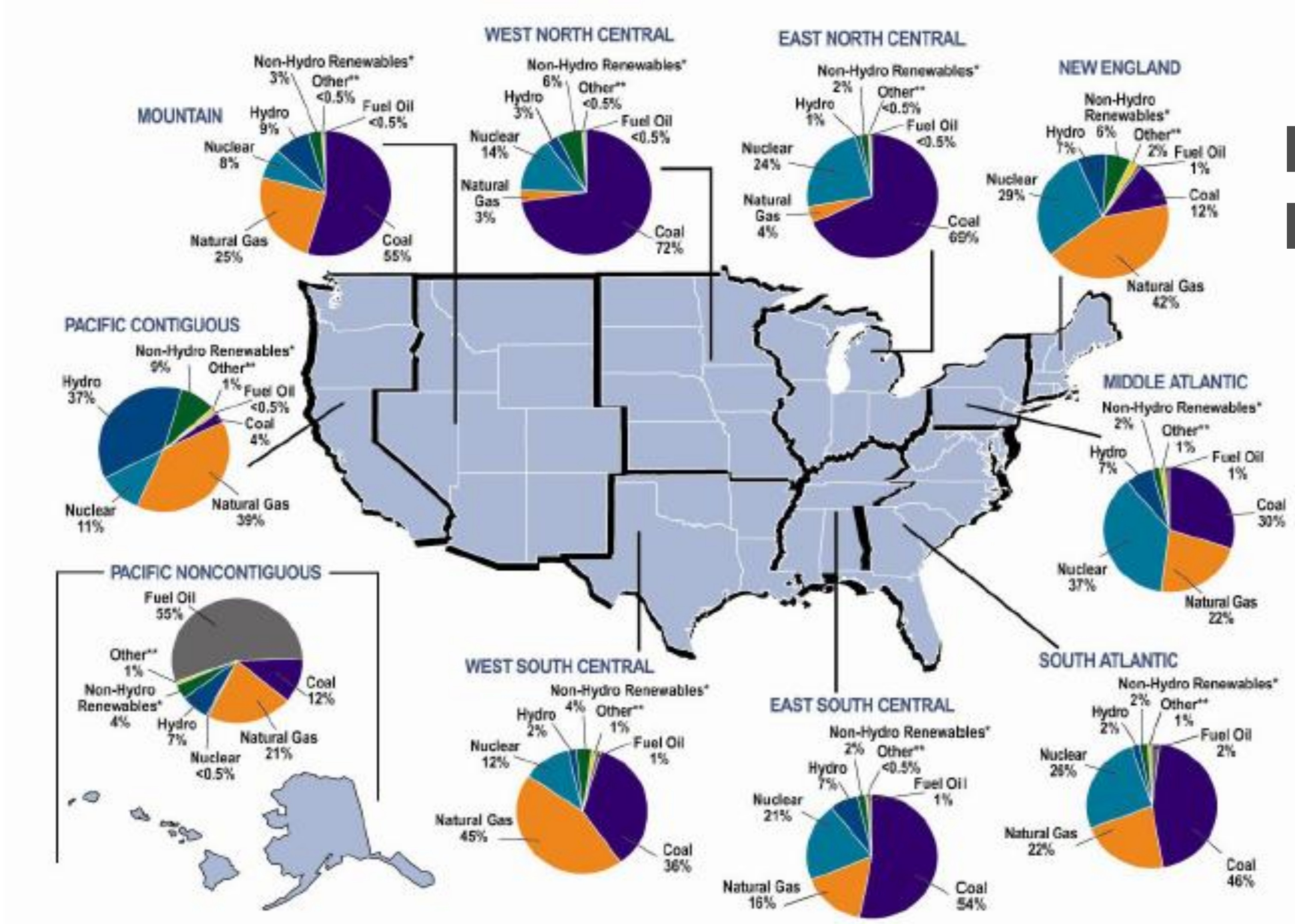
Different Regions of the Country Use Different Fuel Mixes to Generate Electricity



Regional Diversity

*Includes generation by agricultural waste, landfill gas recovery, municipal solid waste, wood, geothermal, non-wood waste, wind, and solar.

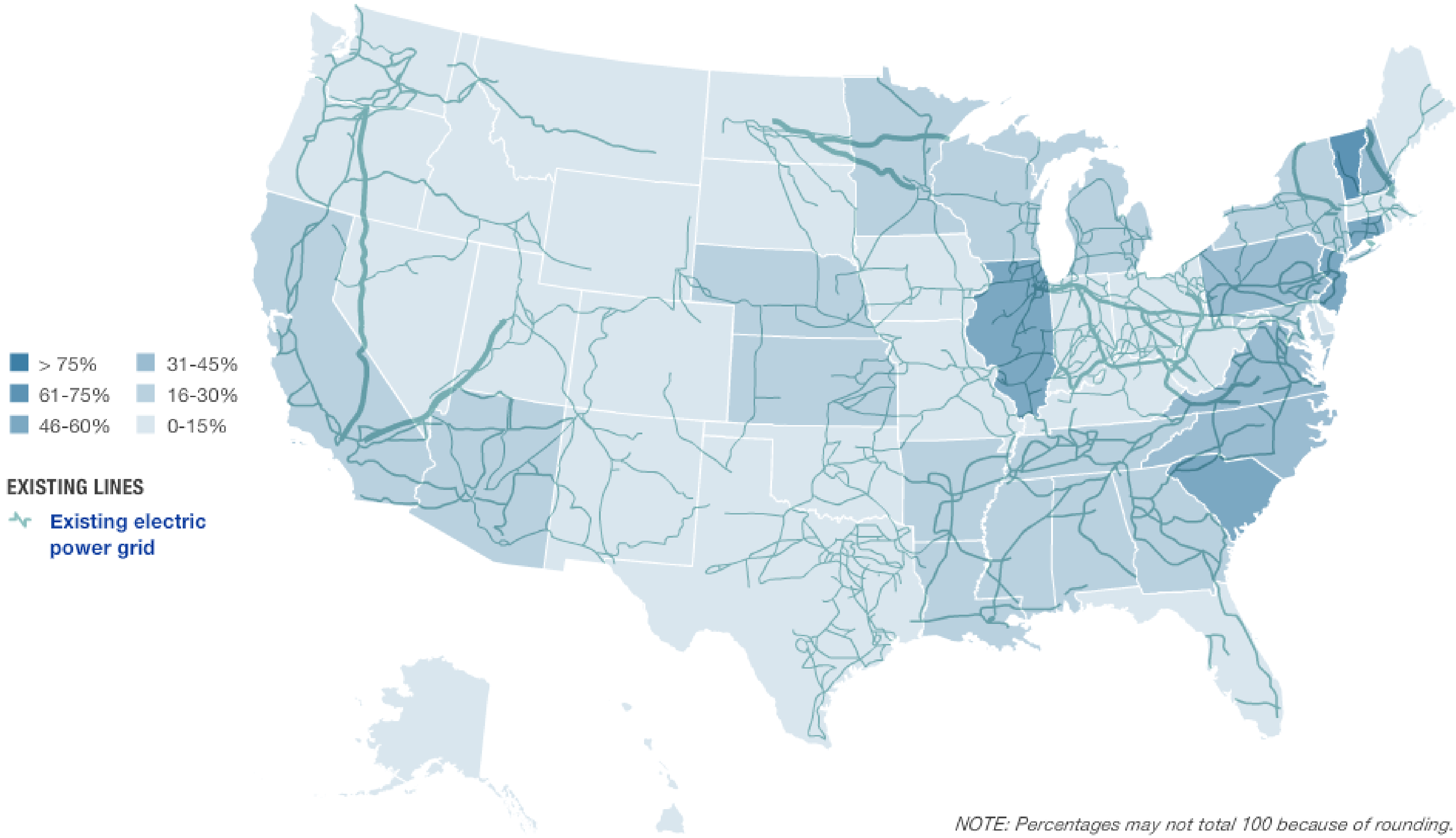
** Includes generation by tires, batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, and miscellaneous technologies.

Sum of components may not add to 100% due to independent rounding.

Source: U.S. Department of Energy, Energy Information Administration, Power Plant Operations Report (EIA-923); 2009 preliminary generation data.

May 2010

Current Nuclear Power Distribution



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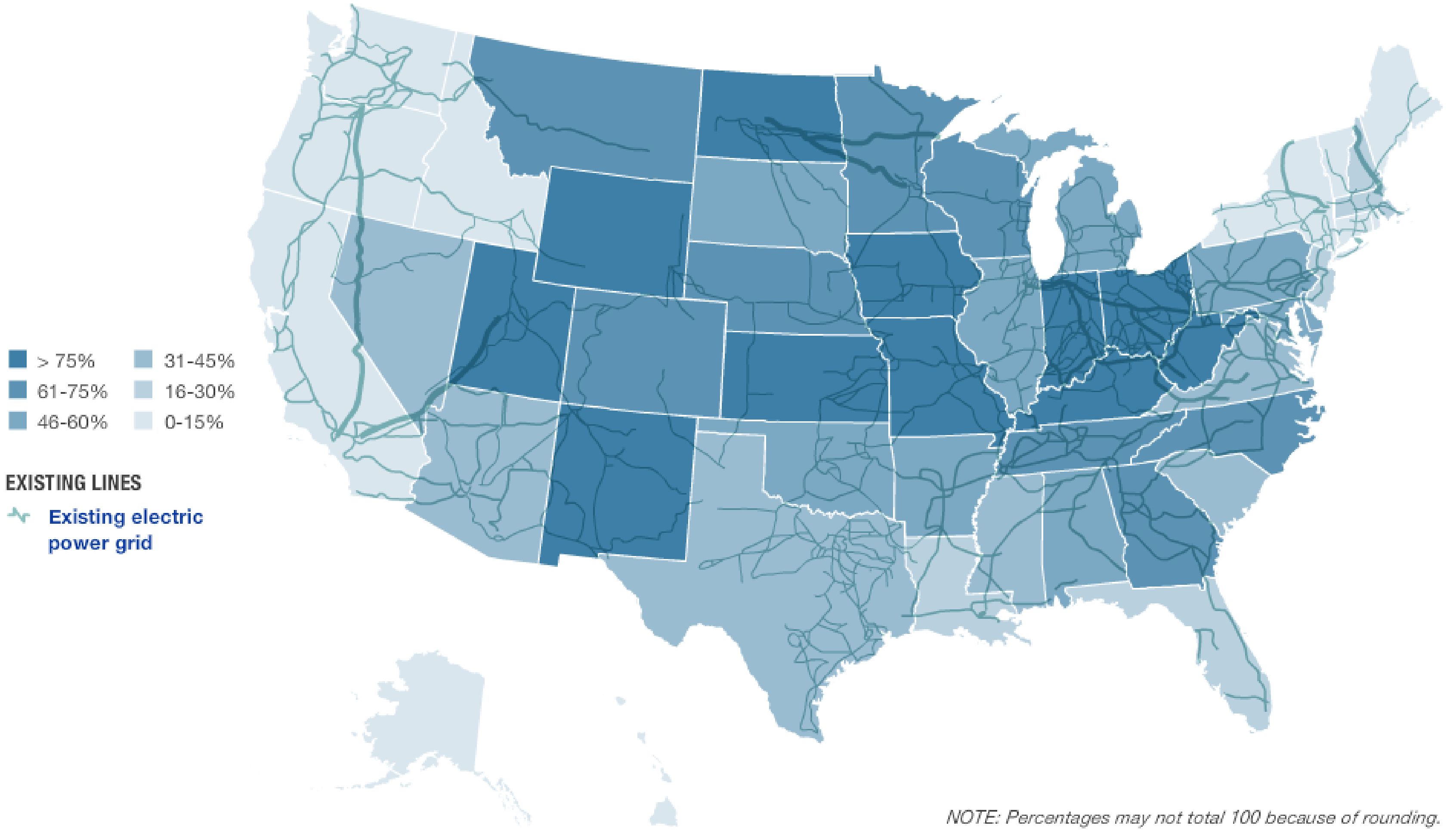
Current Coal Power Sources and Grid Delivery



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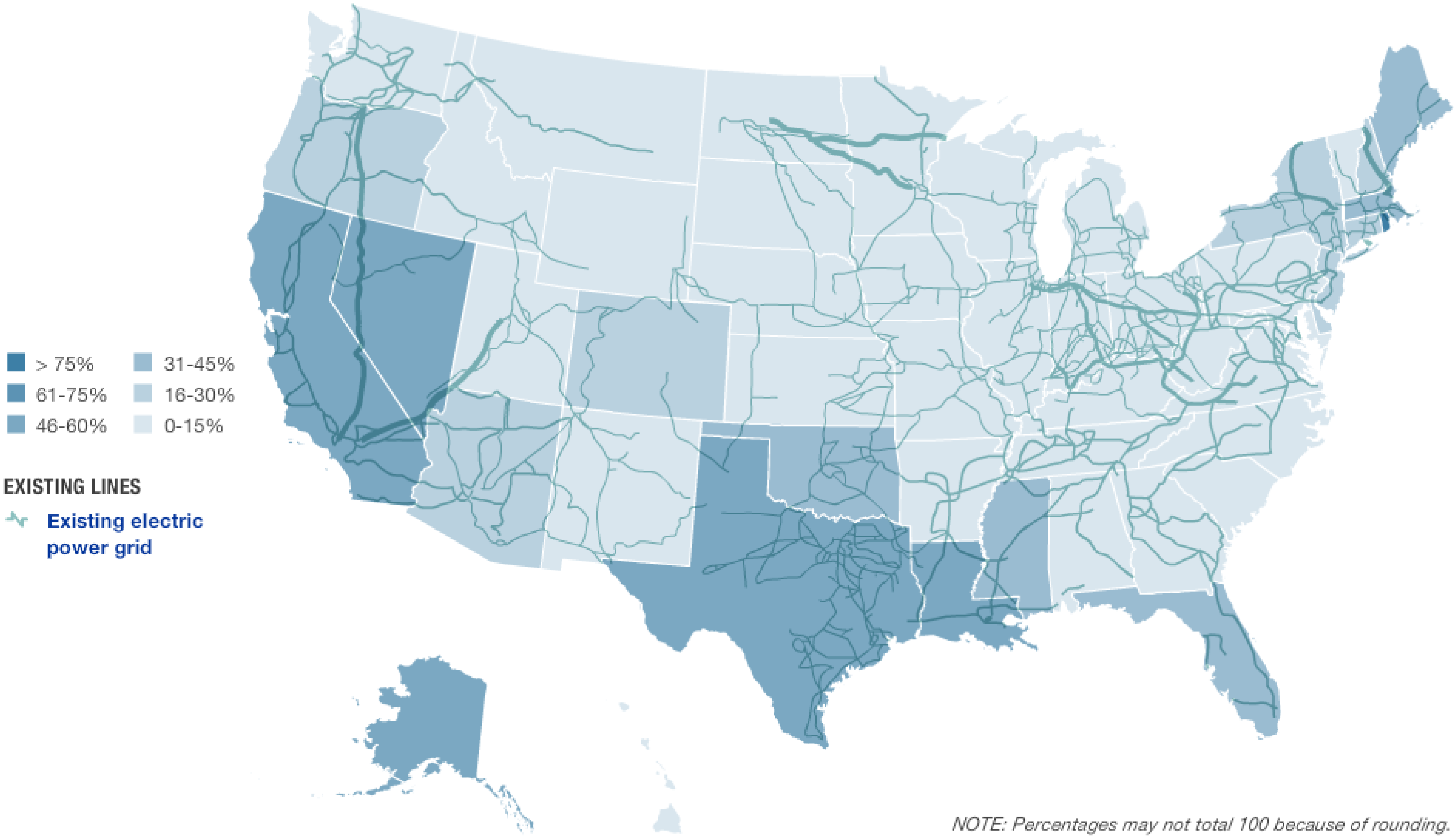
Current Natural Gas (Erd Gas) Power Sources and Grid Delivery



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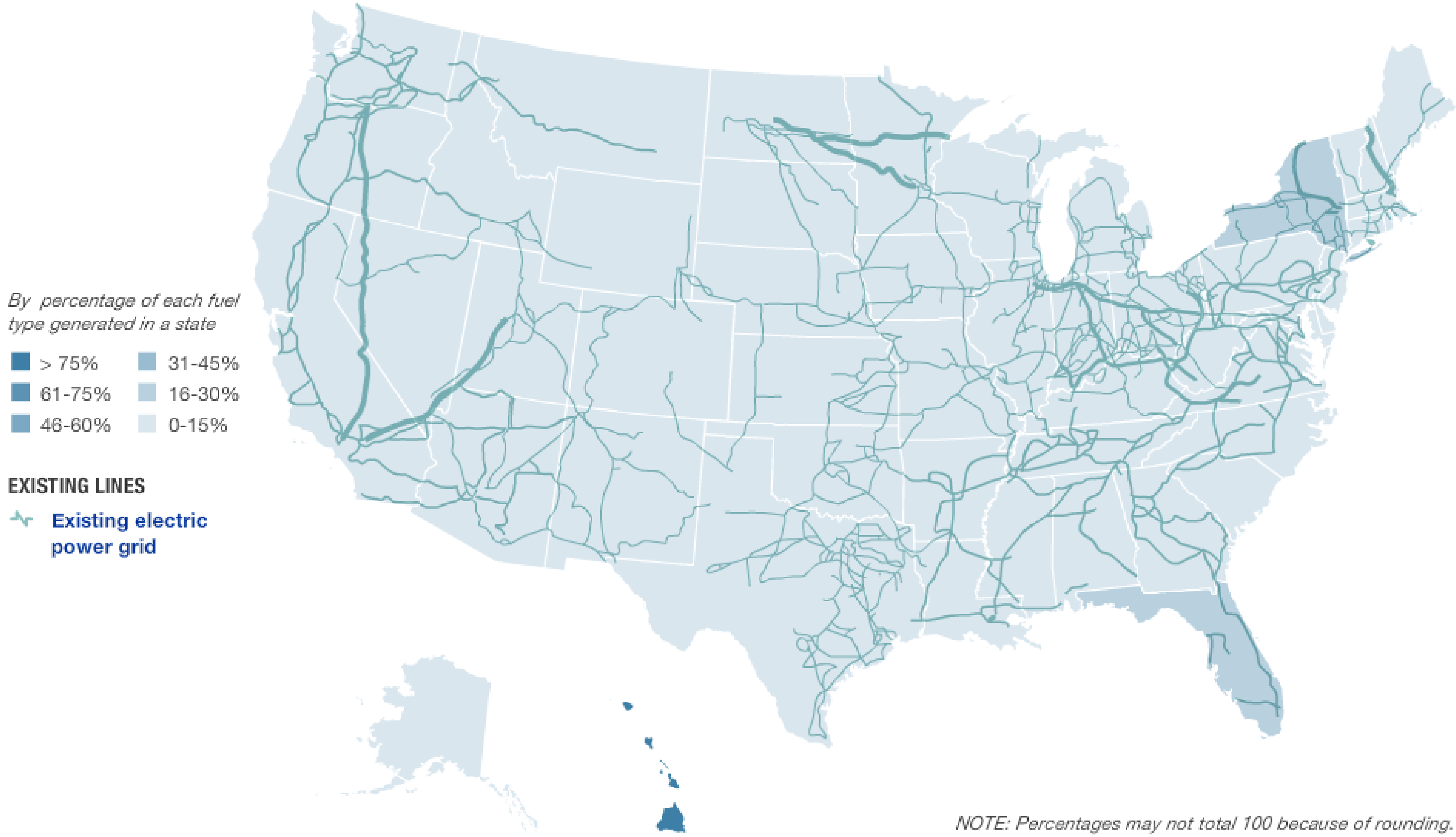
Current Oil (Bunker Fuel) Power Sources and Grid Delivery



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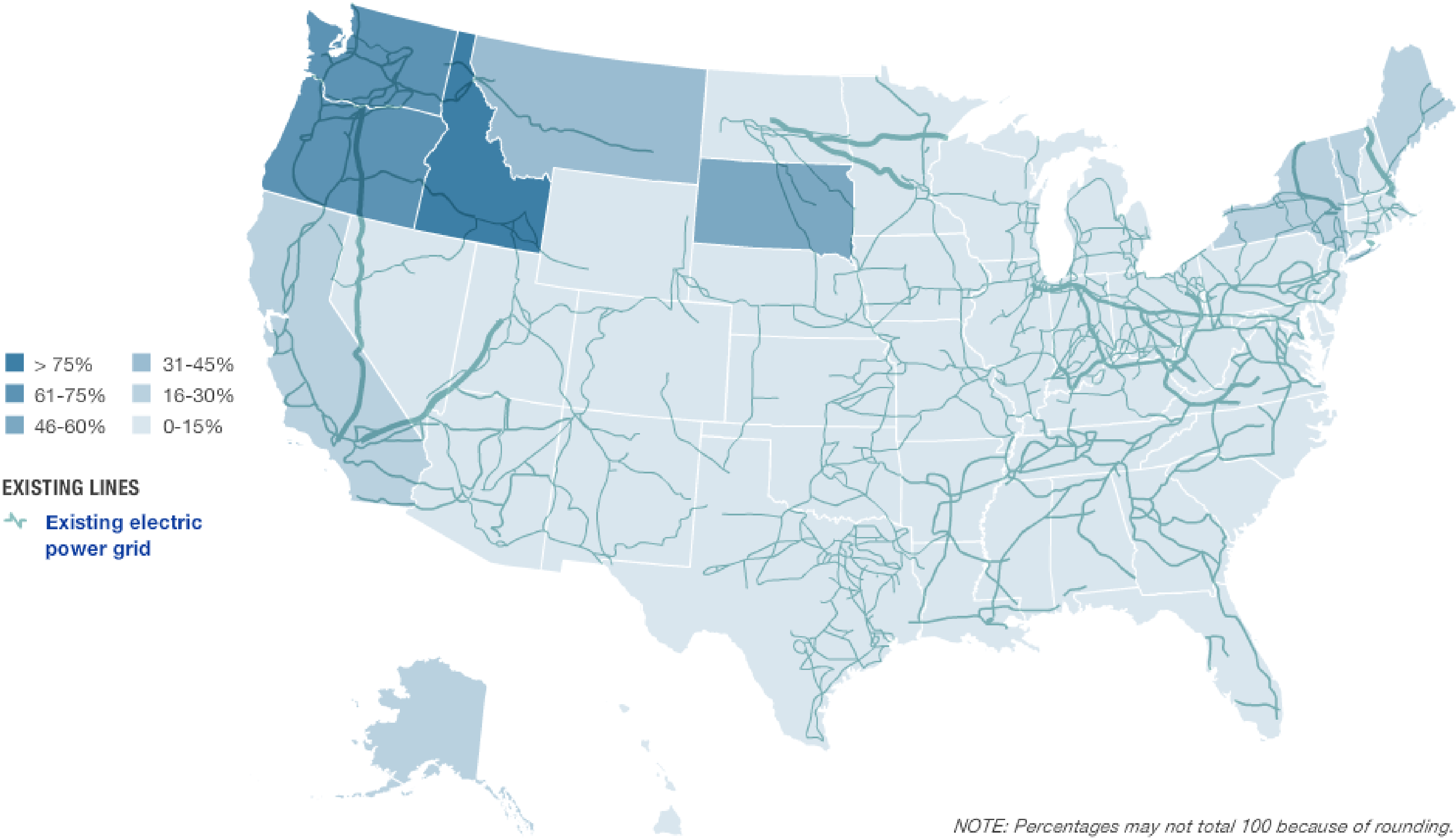
Current Hydroelectric Power Sources and Grid Delivery



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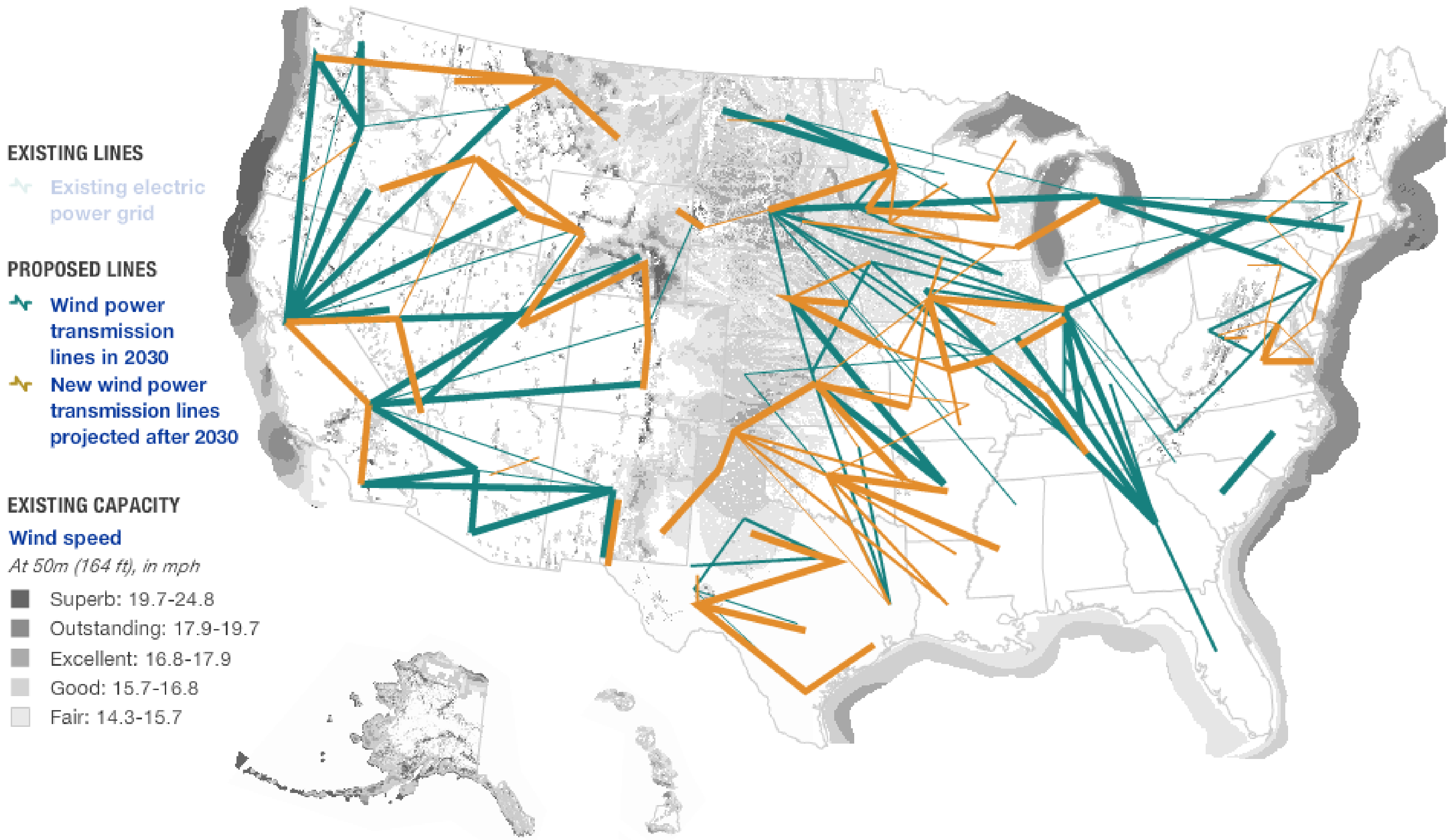
Regarding Renewables...

The physical reality is that the wind, solar, hydrodams, and geothermal resources are usually located in remote places in the middle of the country, while much of the power demand is in urban areas on the coasts.

We cannot change where renewables are best captured or where they are naturally appearing, but we can impact this paradigm and meet the President Obama's goals of securing 25% of our electricity from clean, renewable resources by 2025 by investing in an advanced and larger power infrastructure for electricity to get from the interior to the coasts easily and efficiently.

Wind Power Transmission in 2030 and Beyond



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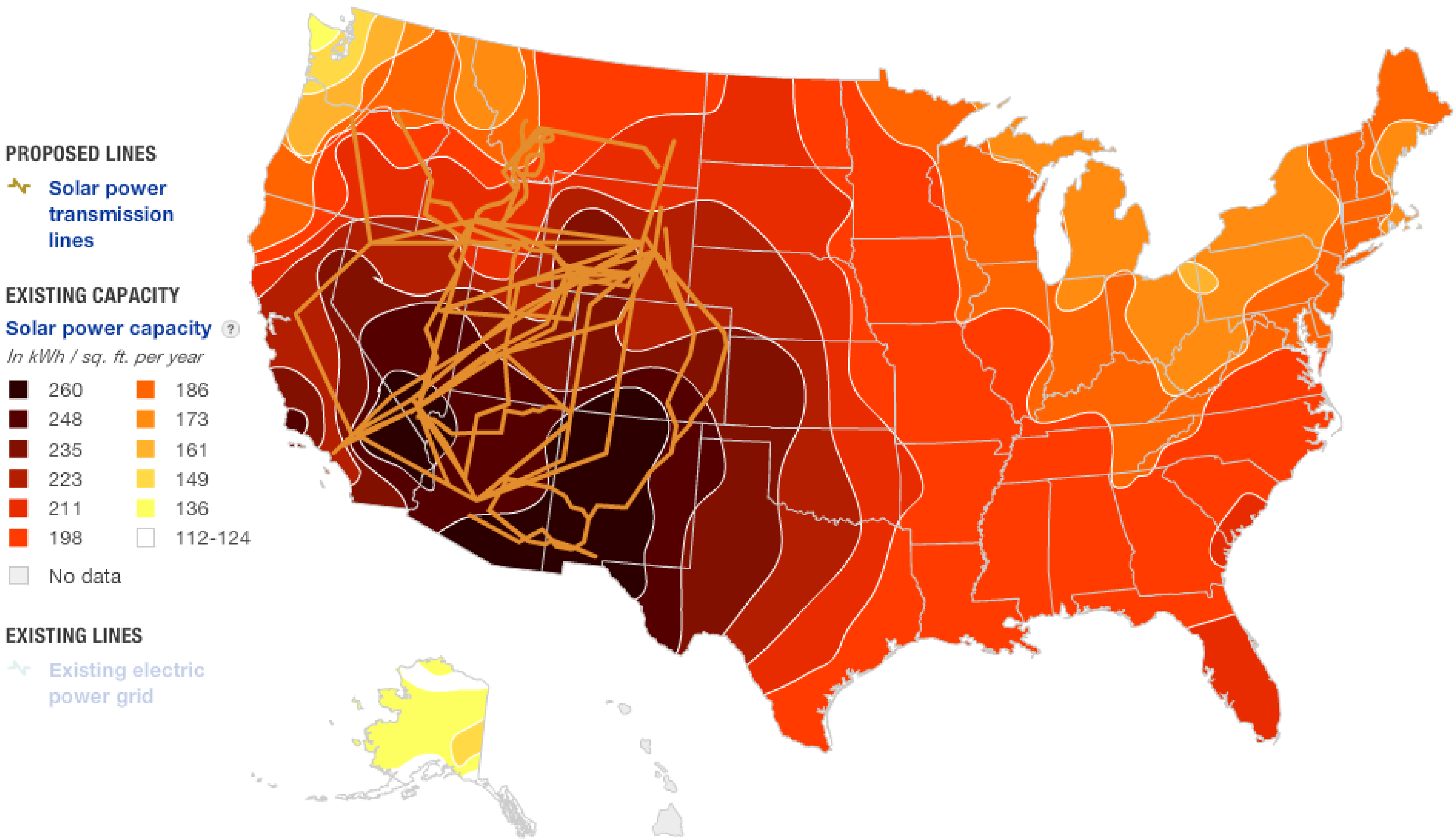
Future Solar Power Distribution and Current Capacity



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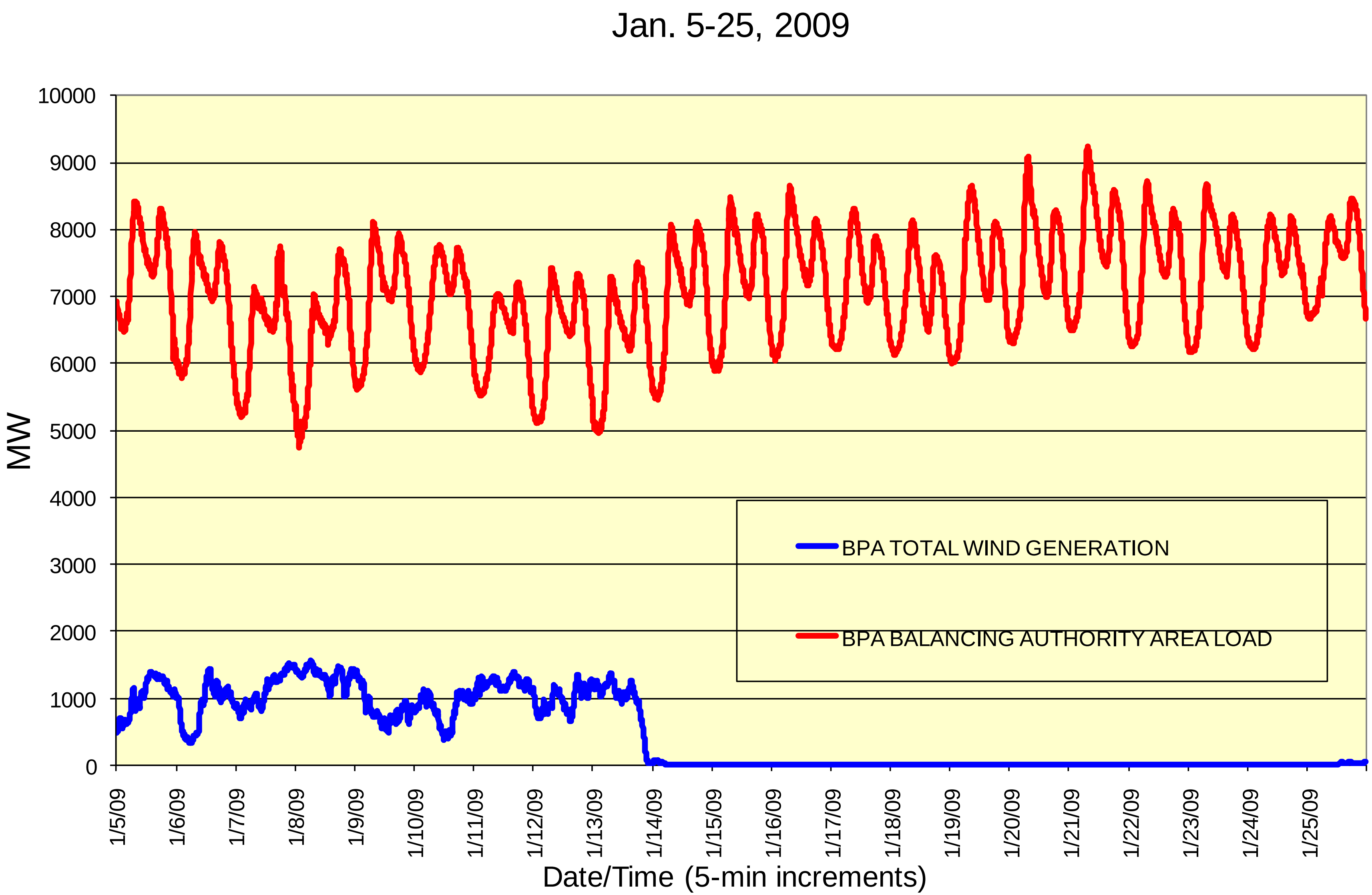
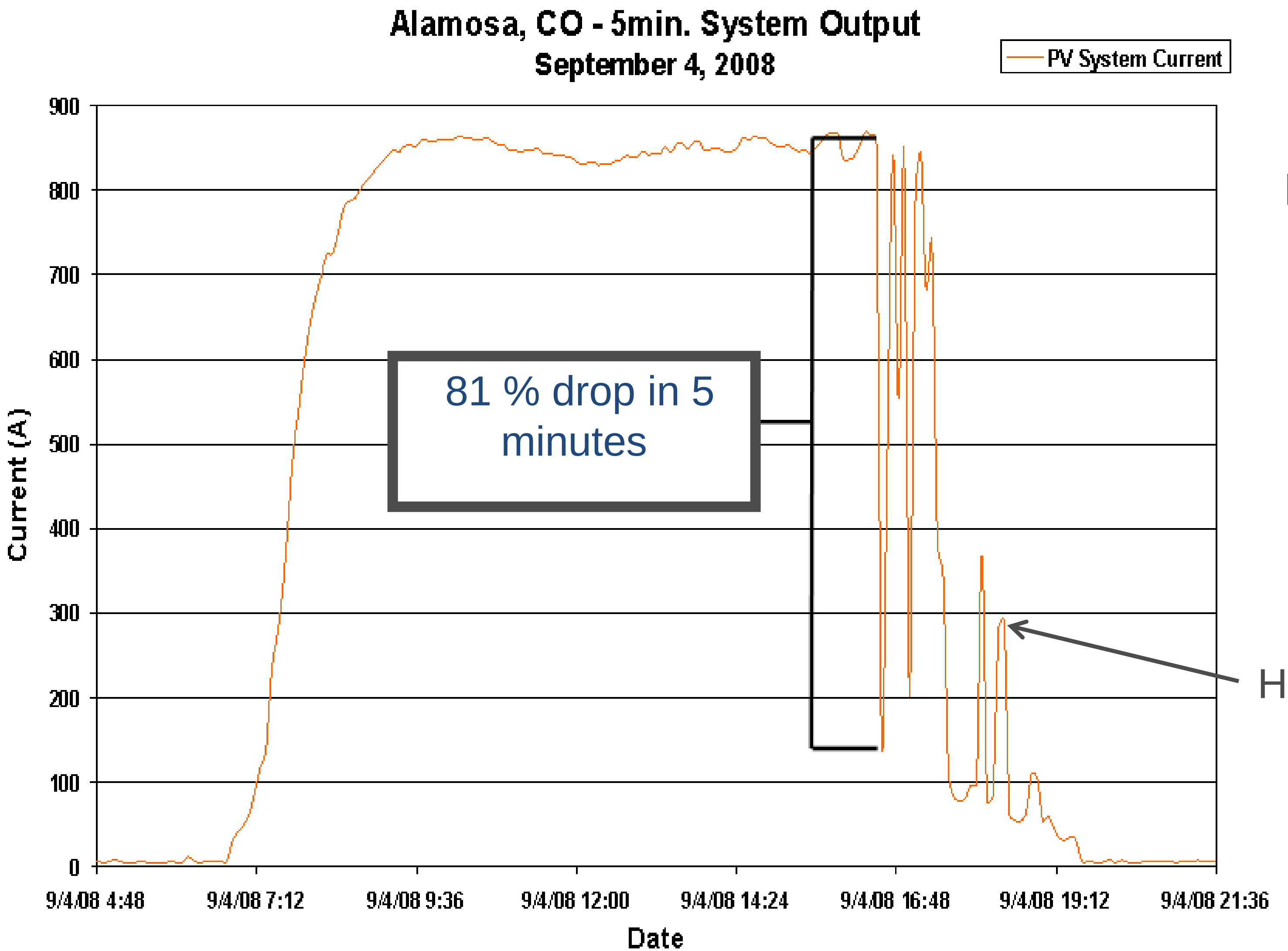
Geography issues aside…

…the current grid has difficulty accommodating variable sources of power like wind and solar energy, the fastest-growing sources of renewable power on the grid. As these resources begin to supply increasing percentages of power to the grid, integrating them into grid operations will become increasingly difficult.

Challenge: Wind Requires Substantial Balancing Reserves



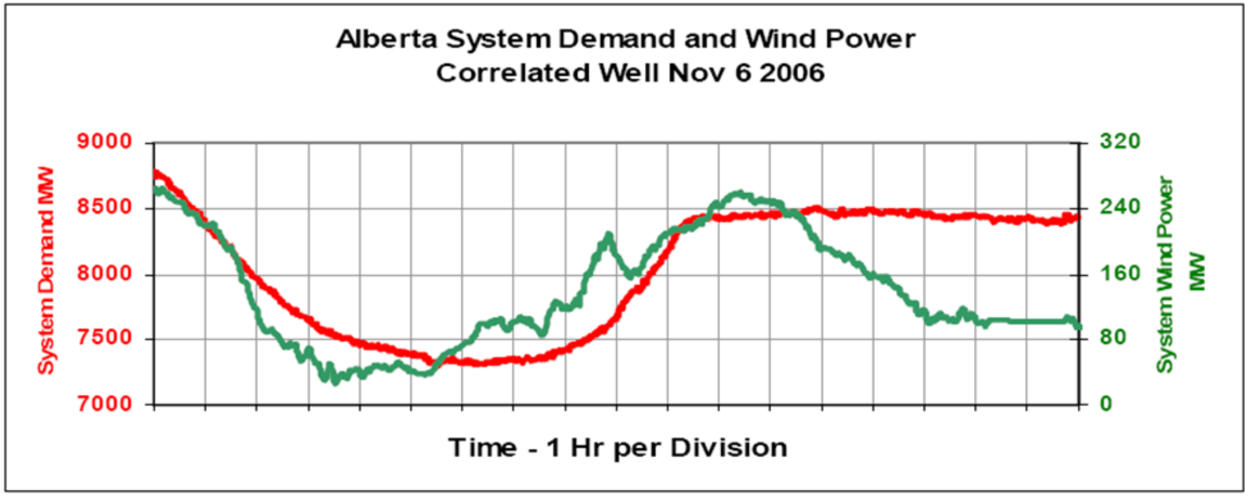
Challenge: Solar Energy Sources Are Highly Variable

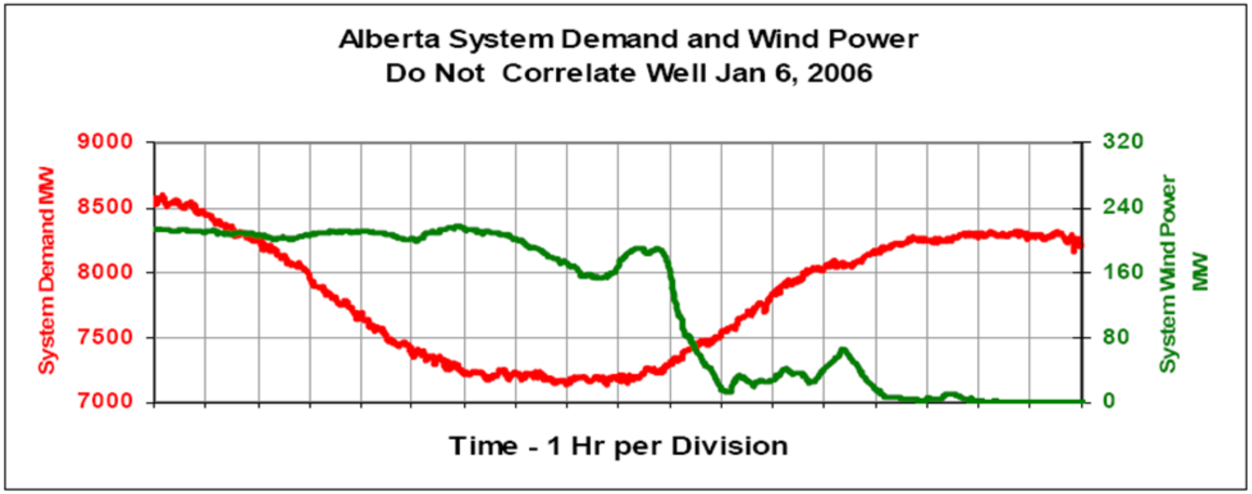


Output from an 8MW solar PV panel in Colorado on 9/4/08

High variability due to clouds

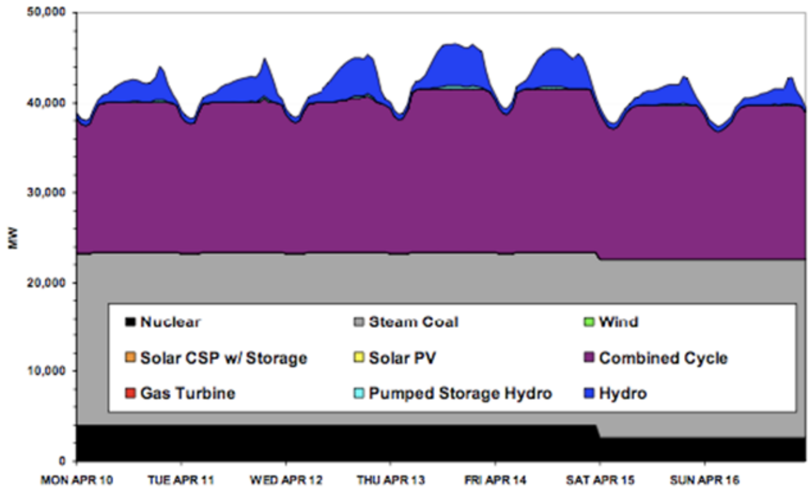
Variable Generation Resources Can Create Challenges for Reliability



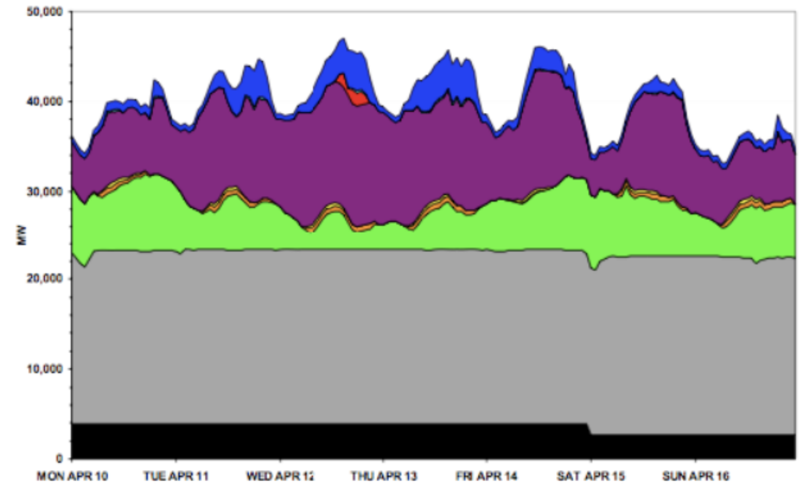


High Penetration of Variable Generation Can Create Operational Challenges

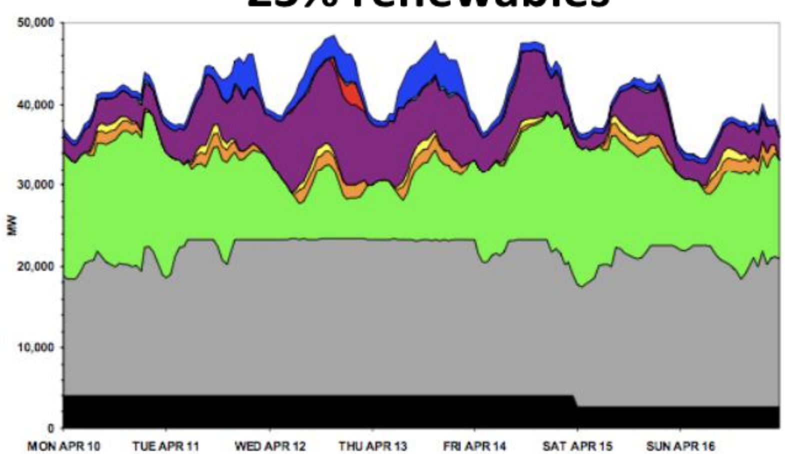
No wind



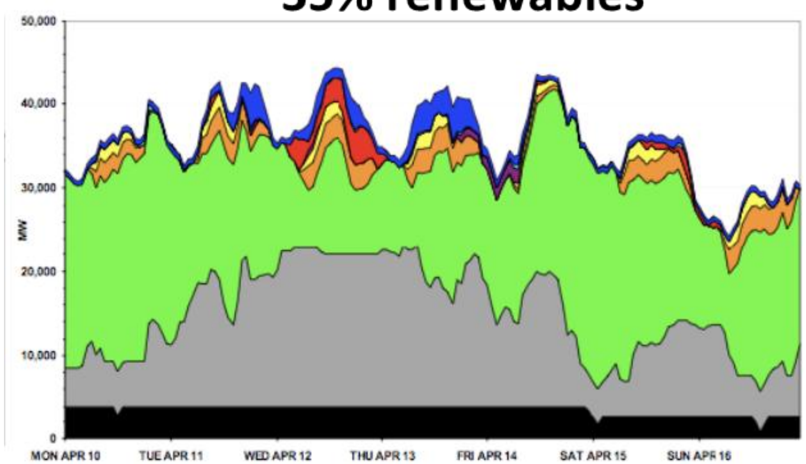
11% renewables



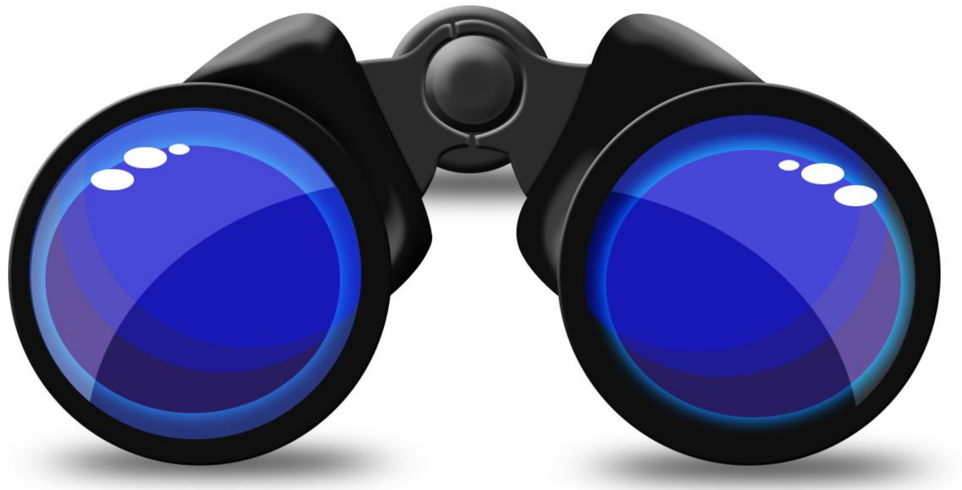
23% renewables



35% renewables

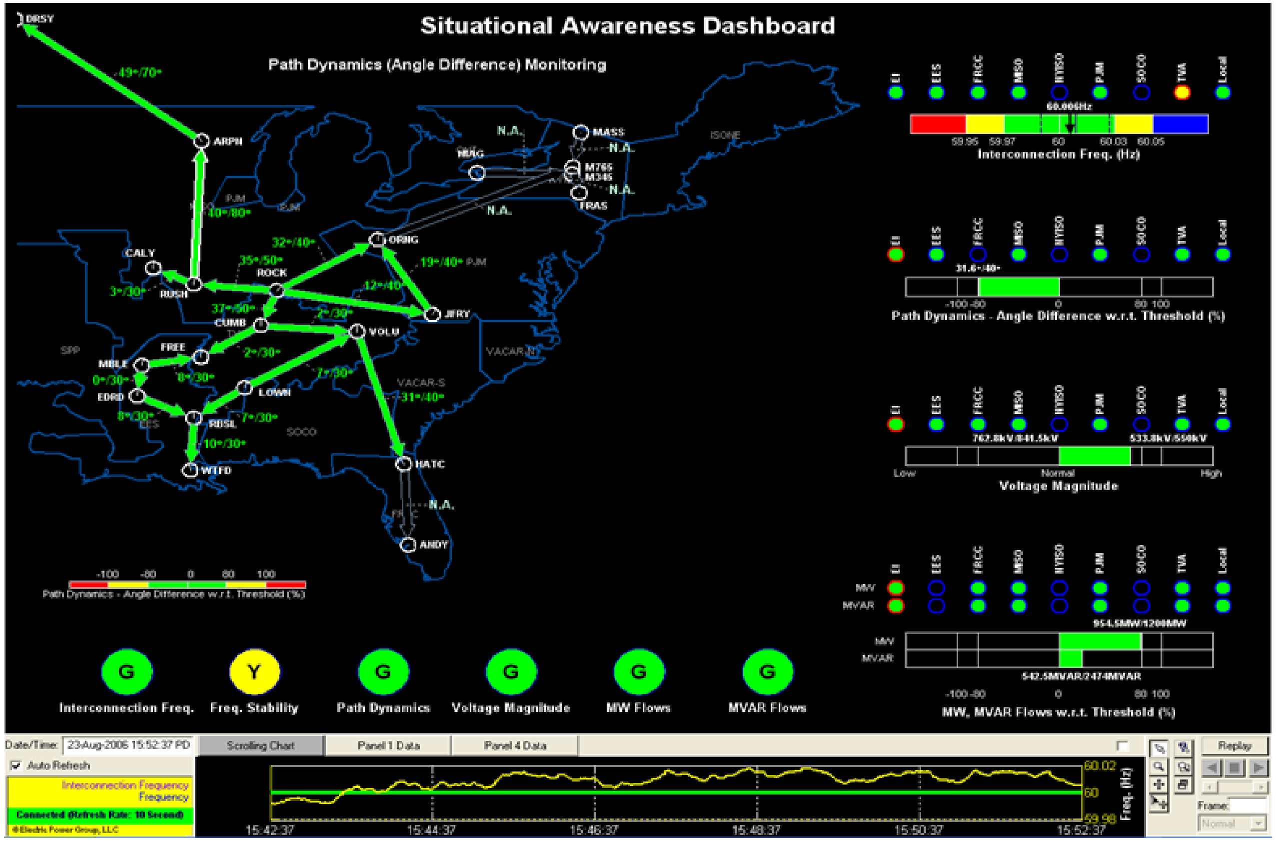


Wide Area Situational Awareness



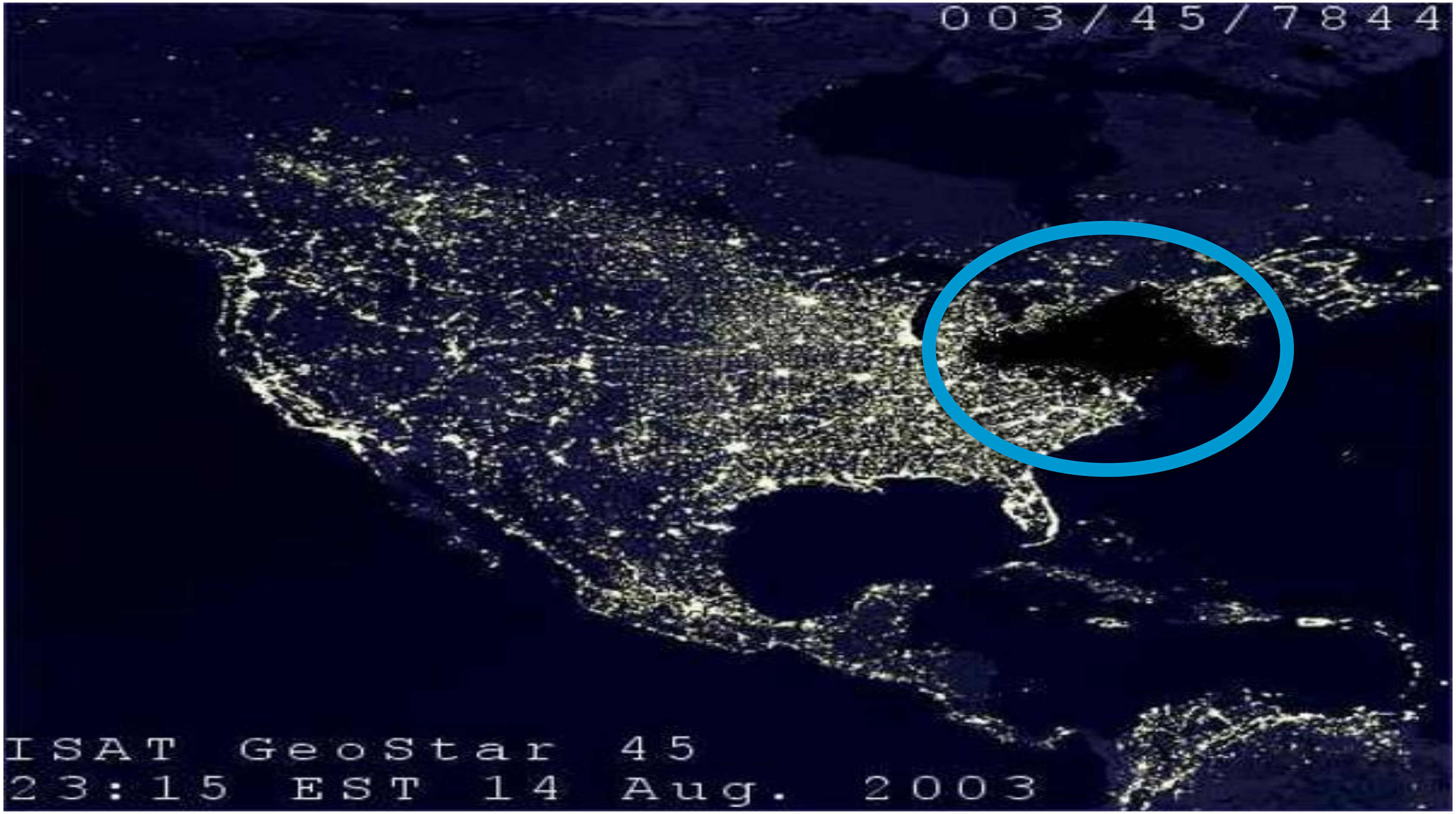
Wide Area Measurement Systems (WAMS) to Enhance Reliability

DOE and NERC are working together closely with industry to enable wide area time-synchronized measurements that will enhance the reliability of the electric power grid through improved situational awareness and other applications

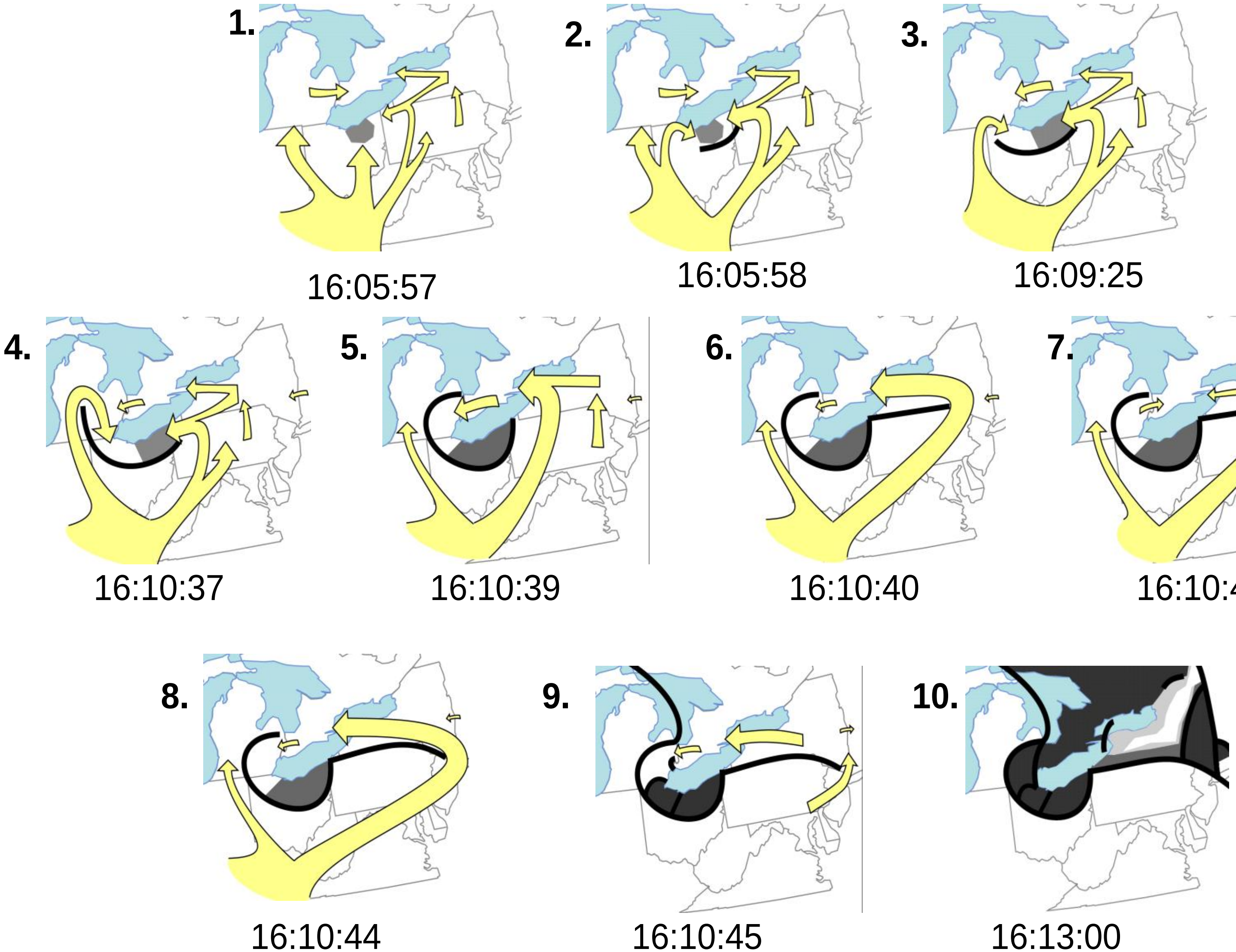


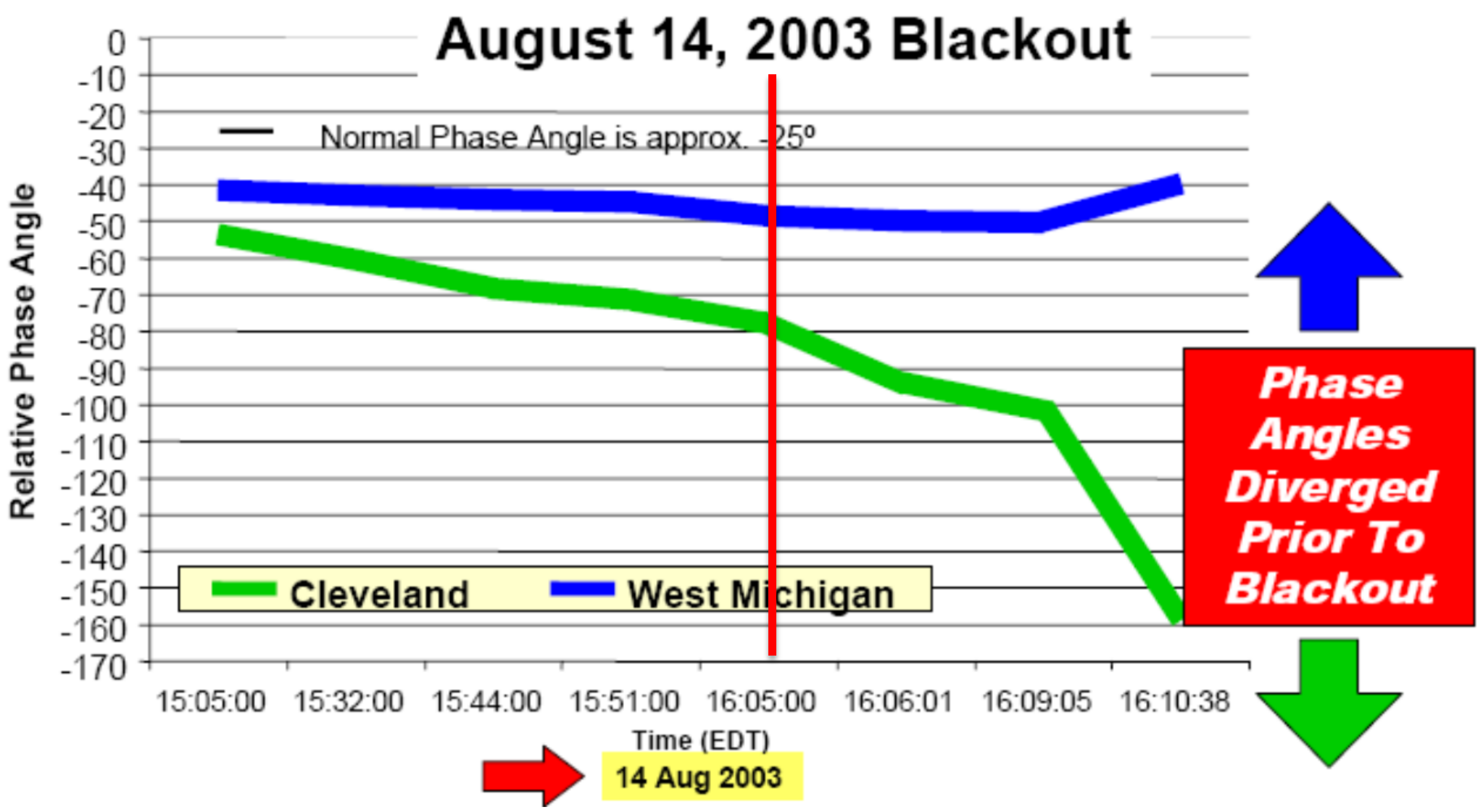
“Better information supports better - and faster - decisions.”

Lack of Wide Area Situational Awareness Contributed to 2003 Blackout



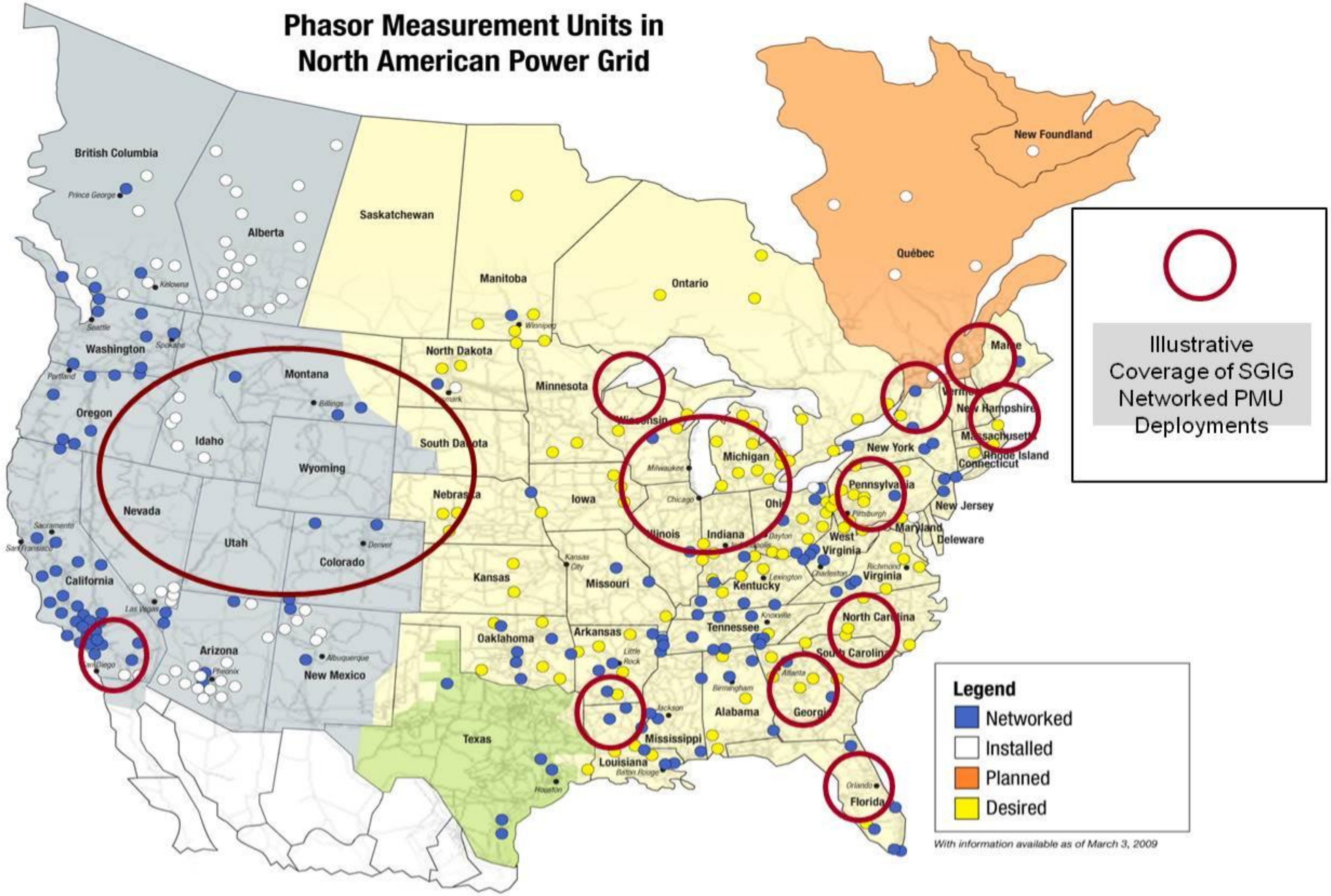
Timeline 2003 Blackout - 6 Minutes to Black





August 14, 2003 Blackout
Normal Phase Angle is approx. -25º
Relative Phase Angle
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
Cleveland
West Michigan
15:05:00
15:32:00
15:44:00
15:51:00
16:05:00
16:06:01
16:09:05
16:10:38
Time (EDT)
14 Aug 2003
Phase Angles Diverged Prior To Blackout

SGIG Networked PMU Deployments Fill Key Gaps for National Coverage



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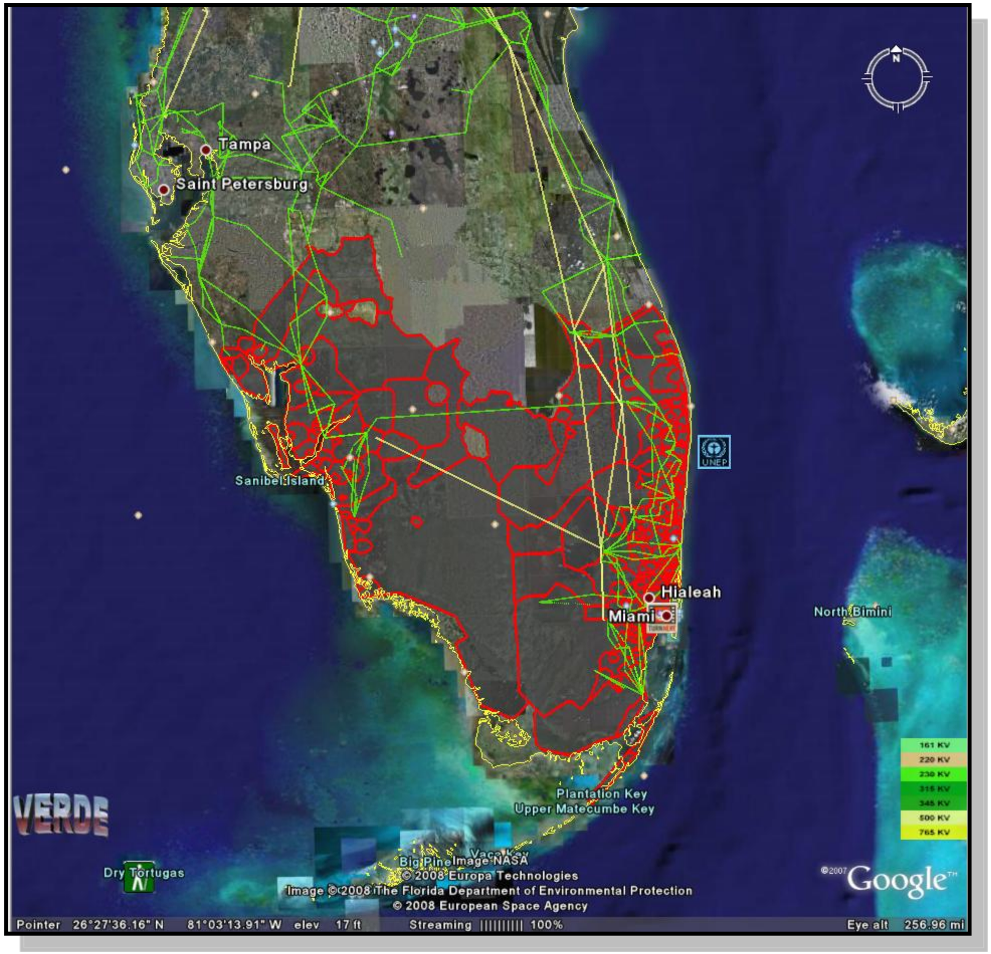
Florida Blackout - February 26, 2008

YouTube - Florida Blackout



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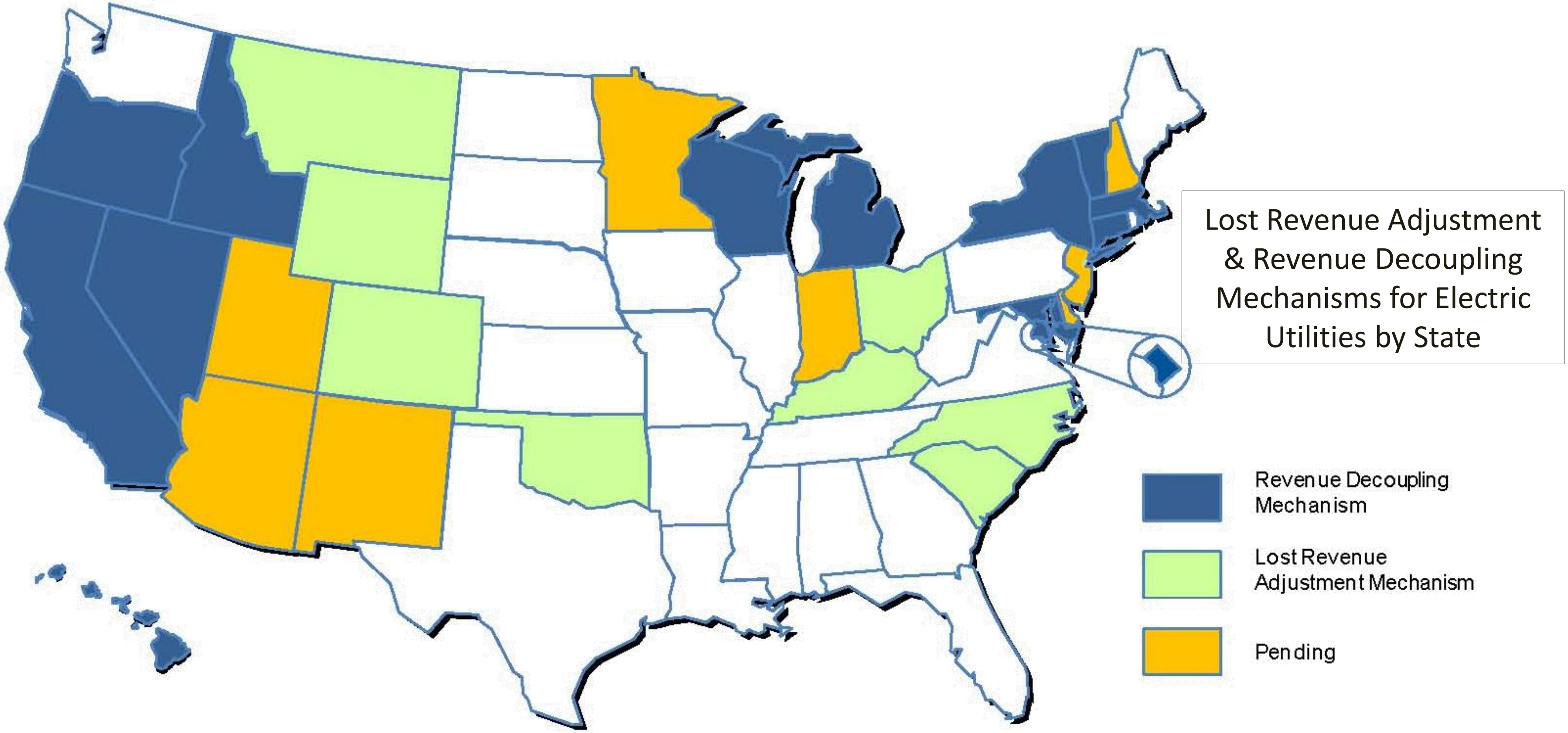
Policy and Regulation

The Challenge of Power Regulation

Some PUCs and utilities aggressively pursuing efficiency,

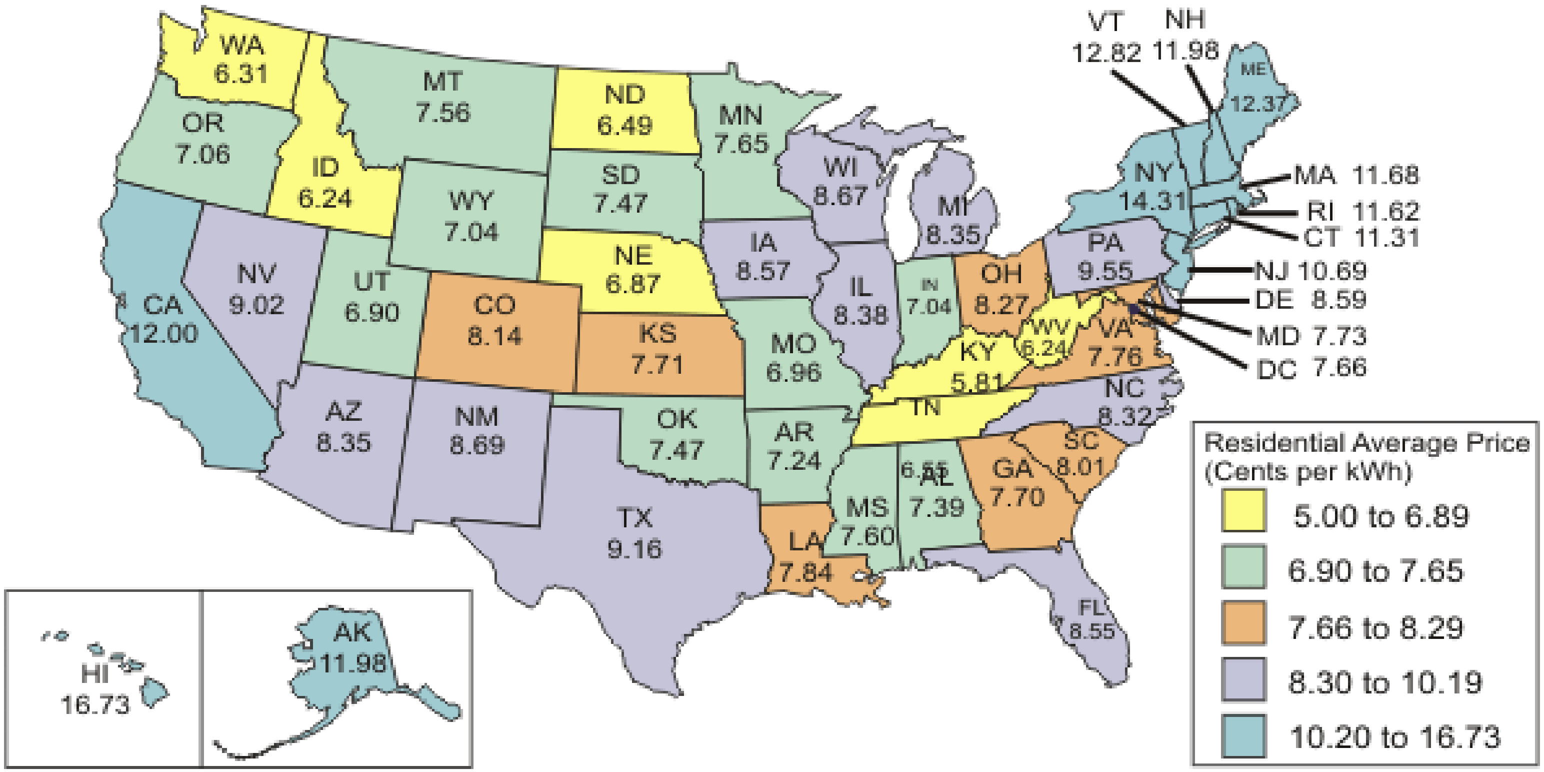
but it's not enough.

Need to break the link between utility sales and utility profits.



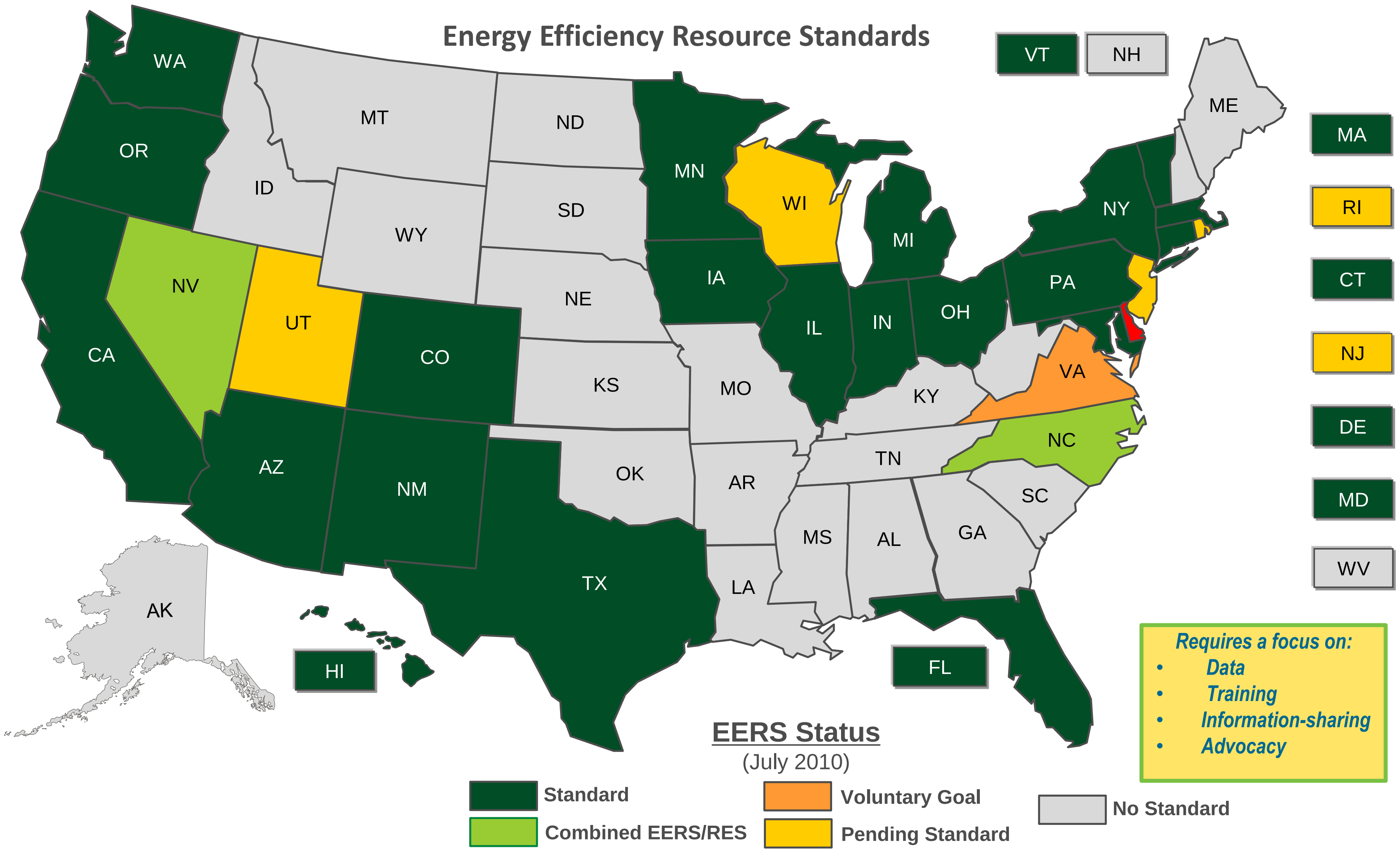
Source: IEE, *State Electric Efficiency Regulatory Frameworks*, July 2010

The Challenge of Power Regulation (continued)



Source: Energy Information Administration, Form EIA-861, "Annual Electric Power Industry Report."

The Challenge of Power Regulation (continued)



Requires a focus on:

- ***Data***
- ***Training***
- ***Information-sharing***
- ***Advocacy***

Source: ACEEE

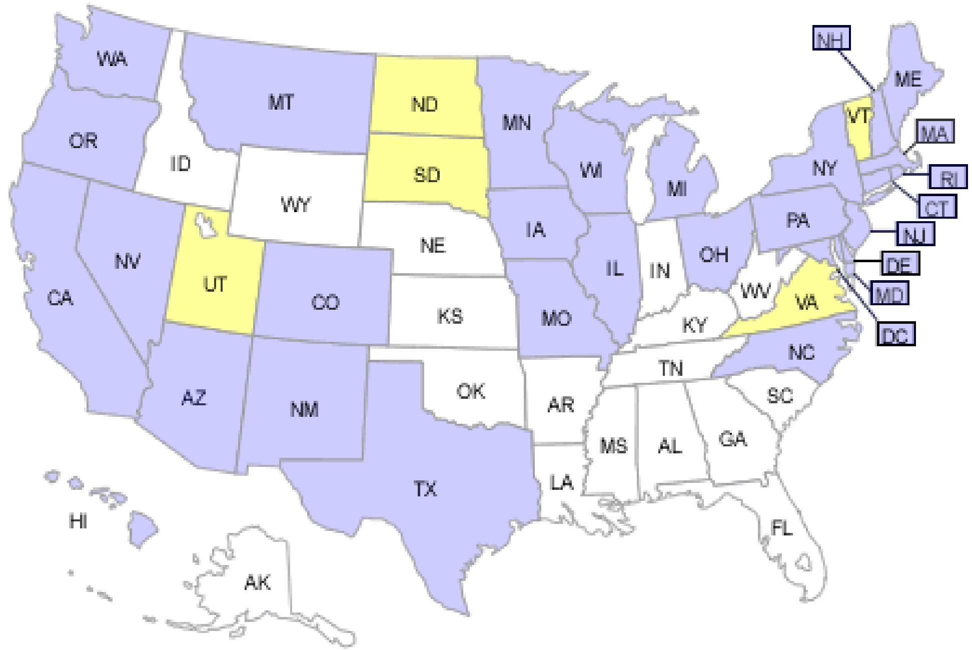
“Smart Grid”

There is no one definition

- Varies from state depending upon policy, market, or electricity prices
- There is not a “one size fits all”

Examples of variables that influence the development of the Smart Grid:

- Renewable Portfolio Standards
- Electric Vehicle goals
- Generation Mix
- High Peak (Peak Demand)-reliability issues
- Weather Events-reliability issues
- Customer/mile



States with RPS
States with RPS Goals

Thank You For Your Time and Attention

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QA