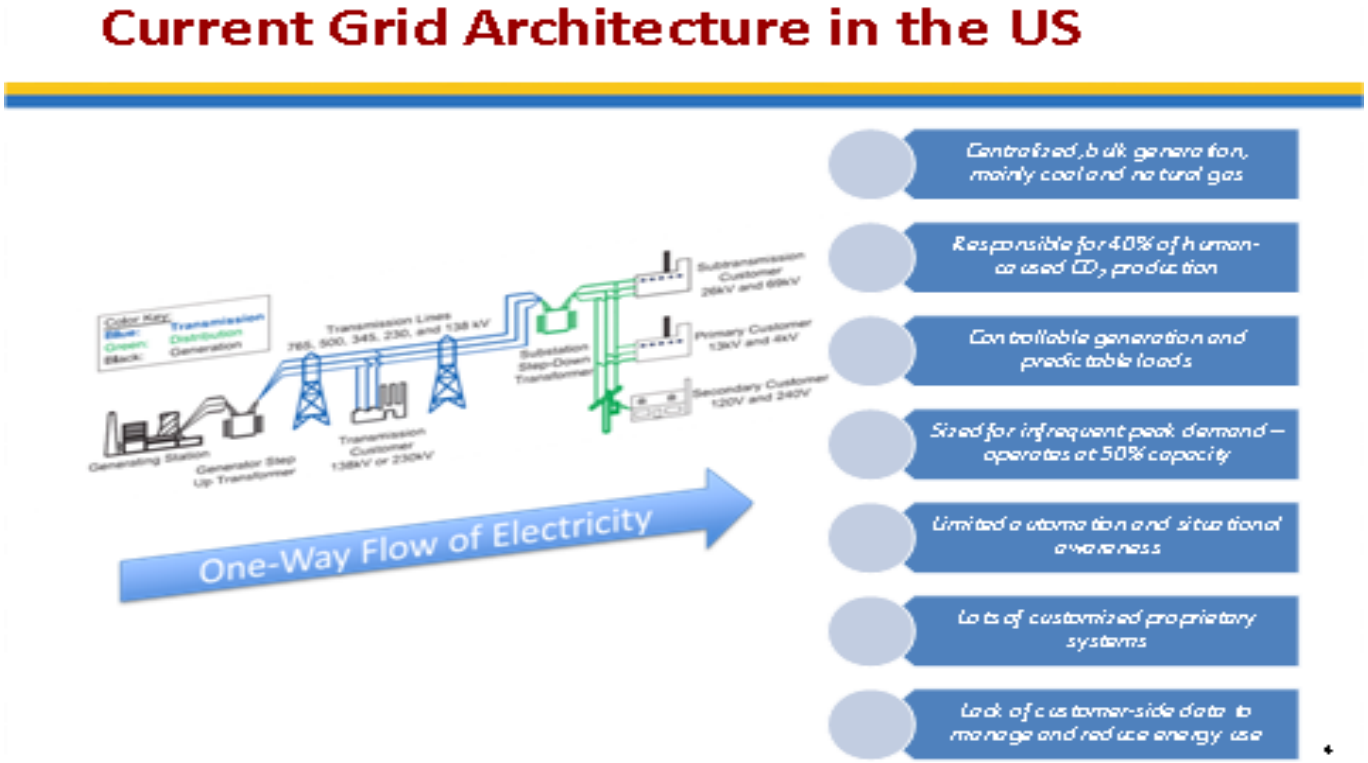
Challenges for the US Electric Distribution System: Opportunities for CMU

Cyndy Wilson
Senior Analyst and Advisor
Office of Energy Policy and Systems Analysis

Overview

- Disclaimer
  - My views
  - Not the findings of the Quadrennial Energy Review (QER)
- The physical electricity supply system—today and tomorrow
- Key challenges:
  - Technology transformation
  - Blurring of lines between distribution and transmission
  - Changing products
  - Empowered customers
  - Erosion of monopoly regulatory and business model
  - Transition
- Opportunities
- Discussion

The U.S. Electricity System--circa 2009



Source: See U.S. Department of Energy, Office of Electricity Delivery and Energy Reliability, Infrastructure Security and Energy Restoration (DOE/OE/ISER) Large Power Transformers and the U.S. Electric Grid, June 2012 ("LPT 2012 Report").

- One way power flows
- Limited communications
- Analog systems

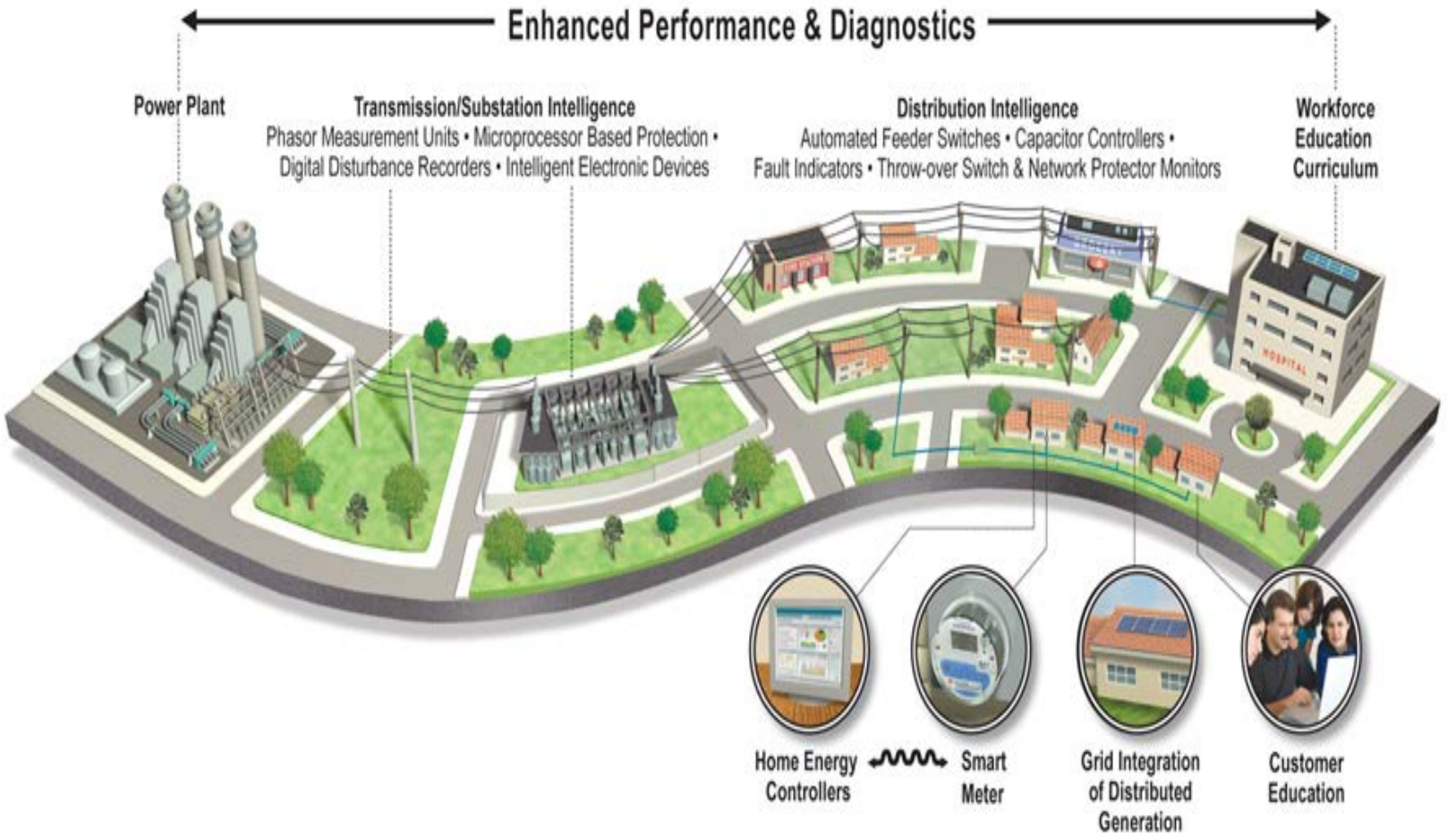
Looking for a “Smart Grid” or “Fractal Grid”

DOE’s definition of “Smart Grid” includes seven principal characteristics:

- enables active consumer participation
- accommodates all generation and storage options
- enables new products, services, and markets
- provides power quality for the digital economy
- optimizes asset utilization and operates efficiently
- anticipates and responds to system disturbances
- operates resiliently against attack and natural disasters

U.S. Department of Energy’s National Energy Technology Laboratory Modern Grid Strategy [NETL 2009]

The Electricity System—Next Generation Physical System



Source: Florida Power and Light; modified by U.S. Department of Energy

The U.S. Electricity System—Modernization Challenges

- Distributed Generation (PVs, microgrids, CHP, etc.)
- Cyber Security
- Big Data
- Advanced Analytics
- Advanced Communication
- Agile Control (segmentability, not segmentation)
- Advanced (Fractal) Architecture

Source: Craig Miller, Maurice Martin, David Pinney, and George Walker, *"Achieving a Resilient and Agile Grid",* The National Rural Electric Cooperative Association. April 2014. http://www.nreca.coop/wp-content/uploads/2014/05/Achieving_a_Resilient_and_Agile_Grid.pdf

Modernization Includes Blurring the Distinctions between Transmission and Distribution

Principles of Fractal Operation (Ideal)

- All segments of the grid operate with the same information and control model—regardless of scale
- Every segment of the grid has a decision-making capability
- The means for exchange of peer-to-peer information are defined clearly in standards
- The rules for when to divide and when to combine are defined clearly

Source: Craig Miller, Maurice Martin, David Pinney, and George Walker, *"Achieving a Resilient and Agile Grid",* The National Rural Electric Cooperative Association. April 2014. http://www.nreca.coop/wp-content/uploads/2014/05/Achieving_a_Resilient_and_Agile_Grid.pdf

Customers Are Wild Card

Distribution System Market Challenge	Distribution System Market Opportunity
• **Declining load growth in many regions (lower energy intensity/greater energy efficiency, increasing self-generation) means declining revenue, when revenue is based on volume**	• Some regions have robust growth
• **Lower revenues, but higher capital requirements**	• Potential new products (differentiated quality, electric vehicles, etc.) create new revenues • Time of use and dynamic rates can lower capital requirements

Customers Are Wild Card

- Customers
  - Historically classified by volume of use or specific equipment (e.g., electric hot water tanks, heat pumps)
  - Historically have resisted higher bills ➔ regulator preference for incremental solutions
  - Are increasingly empowered with controls, self generation and demand sensitive pricing, but how much and when will they respond?—Some want to generate their own electricity; some want to flip a switch
  - Generally don't want their bills to go up

- Cross-subsidy to provide low income customers with "reasonable cost" power is a tradition, i.e., private companies have responsibility to provided social services under the regulatory compact (obligation to serve in exchange for assurances of reasonable return)

Customers Are Wild Card

- Communicating with and marketing to “customers” not “ratepayers” is part of transformation
- General findings are that customers can be segmented
  - Savers
  - Early technology adopters
  - Socially, environmentally motivated
  - Resistant to change
  - Status seekers
  - Etc.
- Age and income demographics may be correlated with the segments; for example, as younger, more technology savvy generations mature, less resistance to new technology

National Policy Goals for the U.S. Grid--Finding Solutions for 50 States and/or X regions

- Secure
- Affordable
- Clean

The “Not-so-United” States Electricity System

- Legal Framework and Institutions
- RTOs/ISOs vs. vertically integrated G&T
- 2000 Distribution Companies—IOU, POU
- Growth rates
- Prices
- Sales per customer (volume and revenues)
- Generation costs
- Generation resources and equipment
- Policies
  - Energy efficiency
  - Renewables adoption
  - GHG reduction
  - Resiliency, adaptation

Implications of the Modernized Distribution Grid –New Institutional Questions

- New jurisdictional and business model issues arise with the blurring between transmission and distribution.
  - What is the role of the RTO/ISO or traditionally vertically integrated utility?
  - Do we need DSOs? If yes, what entity should be the DSO? Who and what rules should govern it?
  - How does technology change affect the roles of FERC and the states?

Implications of the Modernized Grid for Policy—Regulation and Business

- The monopoly business model, the underpinning of vertically integrated companies, distribution companies, and traditional return on assets regulation, is threatened
  - New distributed technologies, especially when combined with storage, create competition, or at least the potential for competition
  - Customers are increasingly managing their consumption, with dependence on utility services changing
- A modernized grid is expected to cost $ billions by 2030 (probably doubling the rate of investment); what will be the source of those funds, especially given electricity customers are notorious for rejecting major rate increases?
- Higher rates likely to further reduce load growth

Implications of the Modernized Grid for Policy—Regulation and Business

- Is this a “death spiral”
- Most vulnerable in the short run
  - Lowest electricity growth/largest decline in sales
  - Highest level of distributed generation penetration
  - Highest level of energy efficiency investment
  - CA, HA, MD, CN, NJ, ME, VT, MA, NY, NH
  - http://www.deloitte.com/us/thenewmath
- The faster the change, the larger the challenge to find new approaches
- Integrated technology/policy/regulatory/stakeholder processes required

Alternative Business Models

- ***Traditional*** -- company provides all electricity supply services, including owning and operating distributed generation and payment is based on regulated rate of return on assets and/or performance payments
- ***Competitive*** --
  - Smart Integrator (from Peter Fox-Penner)—operates the grid, sells services, but never owns the power—aka retail competition at 100% level.
  - Energy Services Utility (also from Fox-Penner)—mission is to deliver energy services – lighting, heat, cooling, etc.
- The NY PSC deliberations—Reforming the Energy Vision (REV)

Transition Is Its Own Challenge

- ***Physical system limits ability to "experiment"***
- ***Net energy metering***— a well intensioned transitional step that has revealed the tip of the financial challenge iceberg
  - Typically pays retail rates for customers to sell excess distributed generation to grid
  - Reduces utility revenues
  - Doesn't price back-up services
  - Increases cross-subsidies from poorer to richer customers

Transition Is Its Own Challenge

- High dependence on ***volumetric rates*** with more need to segment costs and bill accordingly, including costs for back-up power
- Comparisons with transitions in telecom
  - New services
    - landline + cable
    - ➔ cell + internet + cable + on demand + games, etc.
  - New bills

Examples of Intersections of Distribution Challenges with CMU Capabilities

- Information technology applied in systems and networks
- Big data
- Buildings technologies
- Vehicle technologies
- New electric company business models and revenue streams
- Public policy incentives and frameworks
- Marketing to the utility customer
- Economic, psychological and sociological behavior of the customer

Why CMU?

- Interdisciplinary solutions desperately needed
  - Advocacy analysis dominates information available
  - Interdisciplinary approaches increase the chance for balanced, sustainable solutions
- Promoting universal solutions based on regional chauvinism can delay solutions
  - California tends to be on cutting edge, but California solutions don't necessarily work for states with difference characteristics, e.g., lower prices, high consumption, different social values
  - Pacific Northwest takes great pride in energy efficiency accomplishments, despite low, federally subsidized prices
  - PJM or Texas are often cited as "leader" for RTOs—very different systems and political bases—RTO choices may affect transmission/distribution integration
- Need to acknowledge differences among subgroups and to contextualize when and how subgroup results can be extended to others.

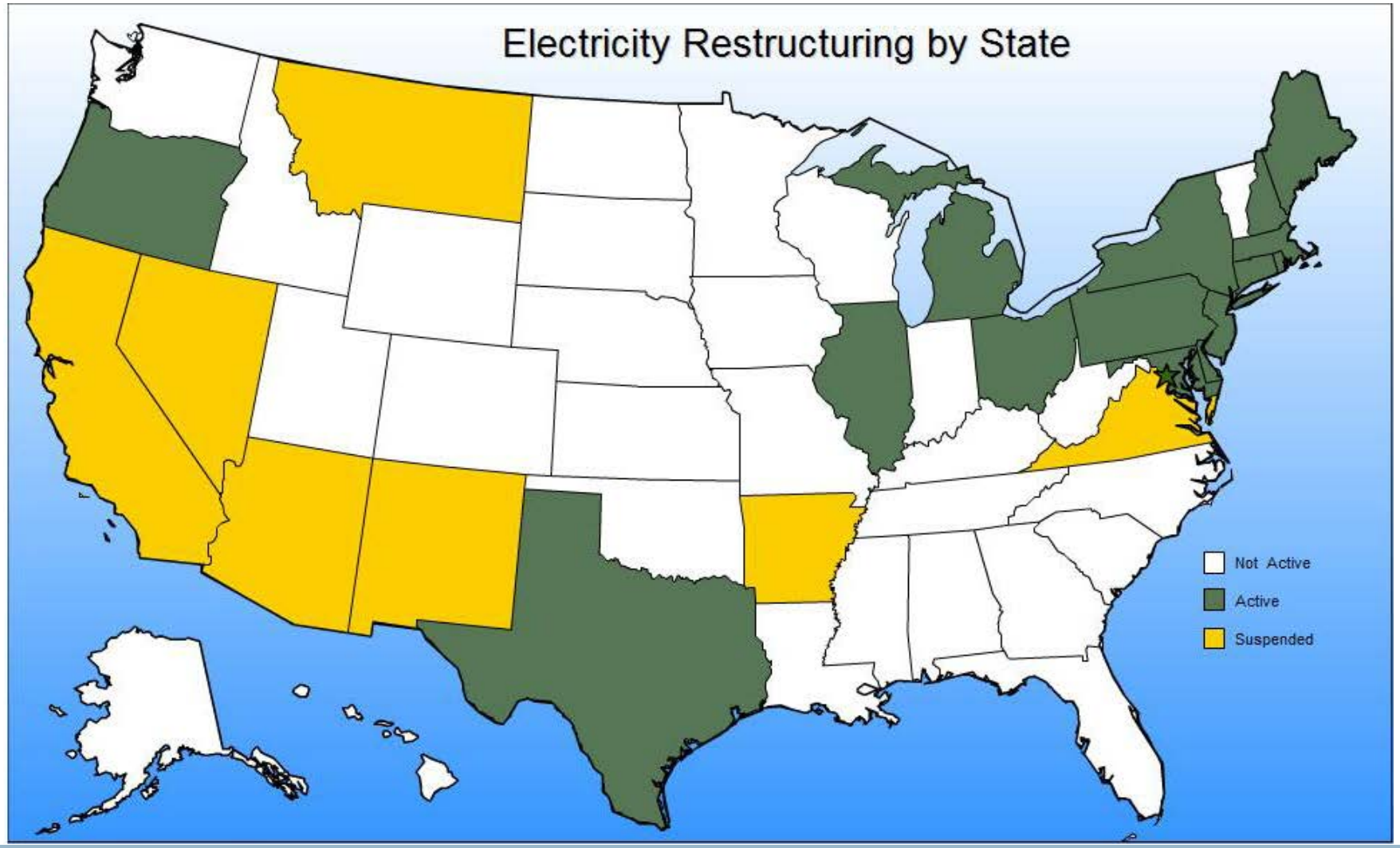
Discussion

Appendix

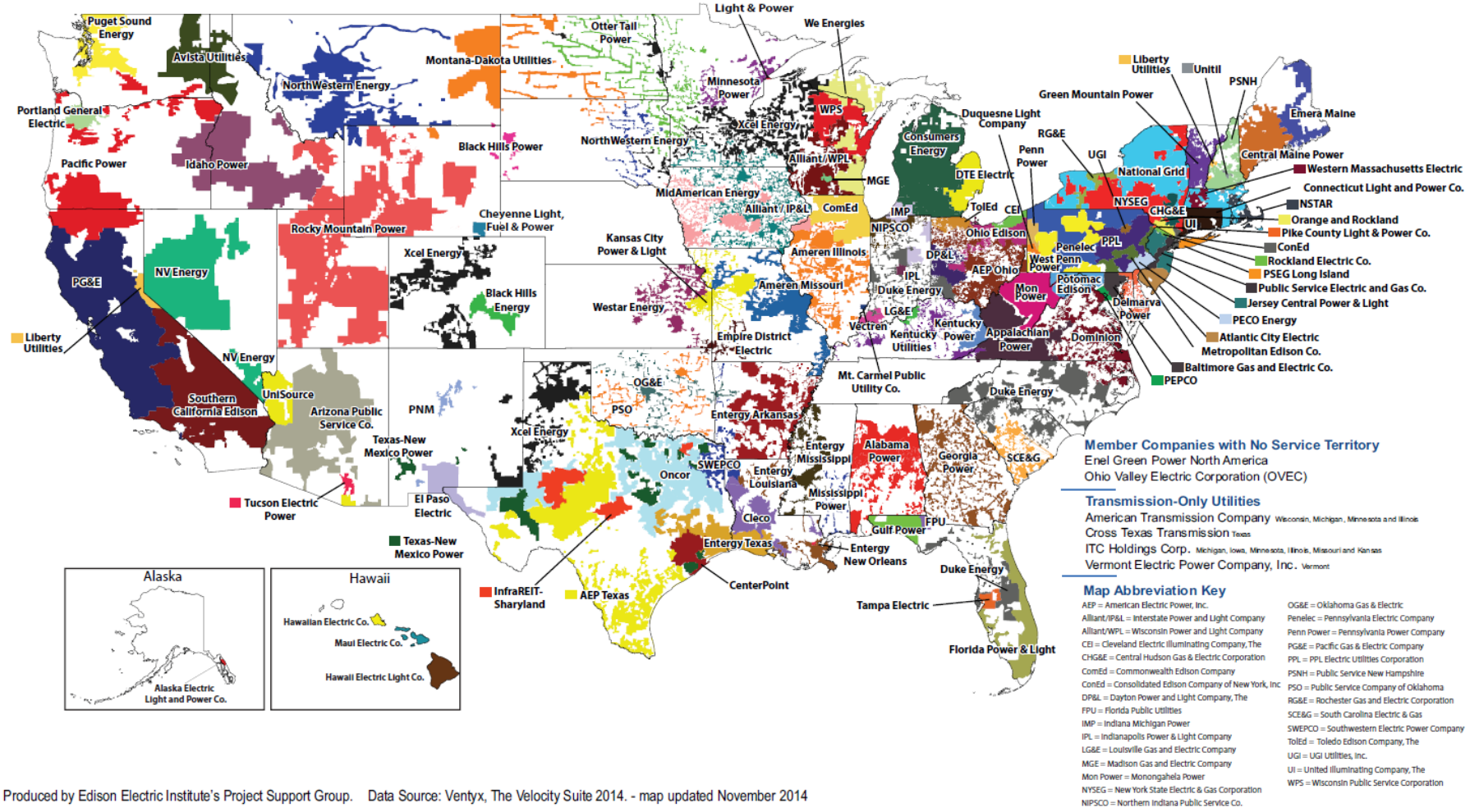
The “Not-so-United” States Electricity System– Legal Framework and Institutions

- Federal authority primarily derives from interstate commerce (FERC), environment and safety (EPA, NRC, et al), oversight of federal lands, and standards (NIST)
- States have jurisdiction over rates, investments affecting those rates, and siting—governors, PSCs/PUCs, legislatures, on the ground stakeholders
- Many cooperatively, municipally, and other publicly owned power entities operate outside of state jurisdiction

The “Not-so-United” States Electricity System–Retail Competition



The “Not-so-United” States Electricity System–Companies



Member Companies with No Service Territory
Enel Green Power North America
Ohio Valley Electric Corporation (OVEC)

Transmission-Only Utilities
American Transmission Company Wisconsin, Michigan, Minnesota and Illinois
Cross Texas Transmission Texas
ITC Holdings Corp. Michigan, Iowa, Minnesota, Illinois, Missouri and Kansas
Vermont Electric Power Company, Inc. Vermont

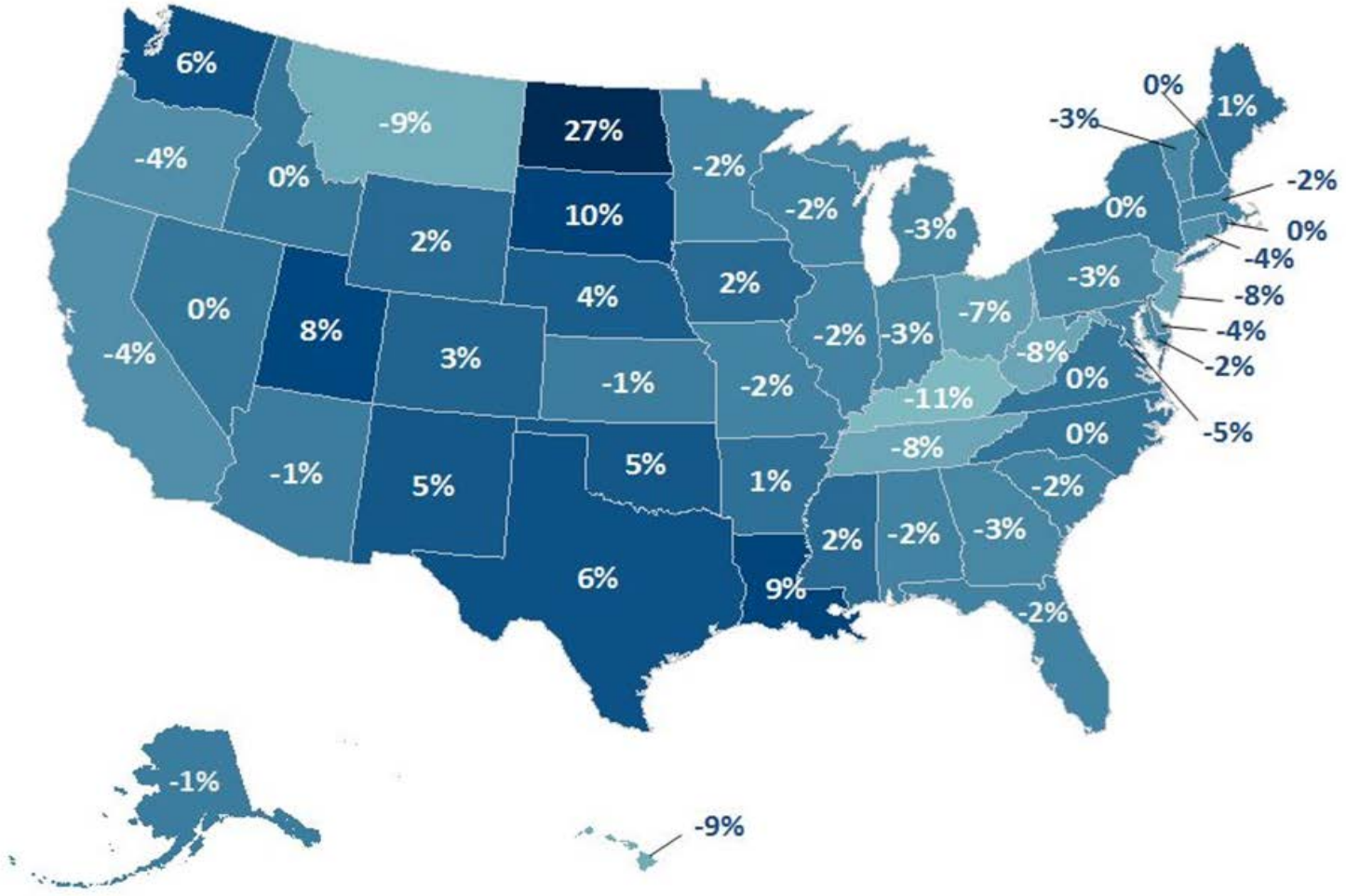
Map Abbreviation Key

AEP = American Electric Power, Inc.
Alliant/IP&L = Interstate Power and Light Company
Alliant/WPL = Wisconsin Power and Light Company
CEI = Cleveland Electric Illuminating Company, The
CHG&E = Central Hudson Gas & Electric Corporation
ComEd = Commonwealth Edison Company
ConEd = Consolidated Edison Company of New York, Inc
DP&L = Dayton Power and Light Company, The
FPU = Florida Public Utilities
IMP = Indiana Michigan Power
IPL = Indianapolis Power & Light Company
LG&E = Louisville Gas and Electric Company
MGE = Madison Gas and Electric Company
Mon Power = Monongahela Power
NYSEG = New York State Electric & Gas Corporation
NIPSCO = Northern Indiana Public Service Co.
OG&E = Oklahoma Gas & Electric
Penelec = Pennsylvania Electric Company
Penn Power = Pennsylvania Power Company
PG&E = Pacific Gas & Electric Company
PPL = PPL Electric Utilities Corporation
PSNH = Public Service New Hampshire
PSO = Public Service Company of Oklahoma
RG&E = Rochester Gas and Electric Corporation
SCE&G = South Carolina Electric & Gas
SWEPCO = Southwestern Electric Power Company
TolEd = Toledo Edison Company, The
UGI = UGI Utilities, Inc.
UI = United Illuminating Company, The
WPS = Wisconsin Public Service Corporation

Produced by Edison Electric Institute's Project Support Group. Data Source: Ventyx, The Velocity Suite 2014. - map updated November 2014

The “Not-so-United” States Electricity System--Growth

Percent Change in Retail Sales (kWh), 2008–2013



Source: EIA. http://www.eia.gov/electricity/data/browser

The “Not-so-United” States Electricity System--Sales

SELECTED US STATE DEGREE DAYS, RESIDENTIAL RETAIL ELECTRICITY RATES AND TOTAL ANNUAL RESIDENTIAL UTILITY REVENUE (AVE RATES, $/KWH)

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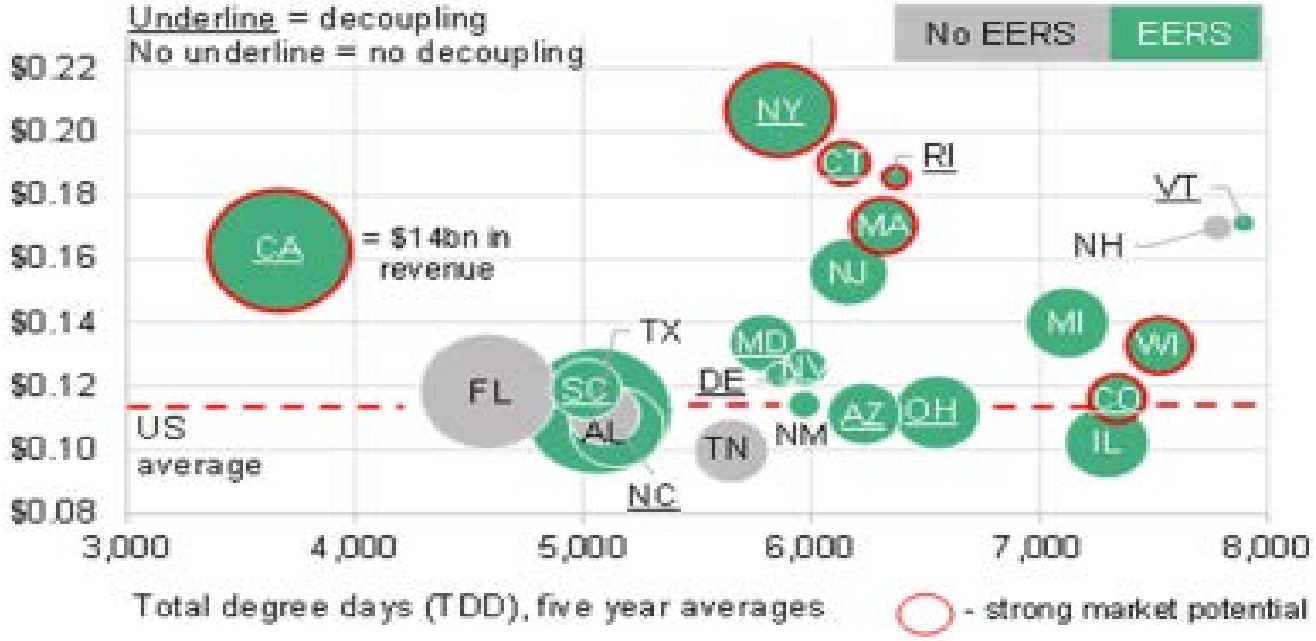

Source: Bloomberg New Energy Finance, EIA, http://www.degreedays.net/ Note: Degree days are averaged for selected major cities in each state using a 65°F base temperature and five-year annual averages; cooling and heating degree days are combined because HEM devices can manage both heating and cooling loads, including non-electrical loads. Bubble sizes represent total annual residential utility revenue. Hawaii not shown because its metrics distort the graph for the other states (retail rate: $0.37/kWh, 4,300 CDDs, $1bn in annual residential utility revenue).

The “Not-so-United” States Electricity System--Generation

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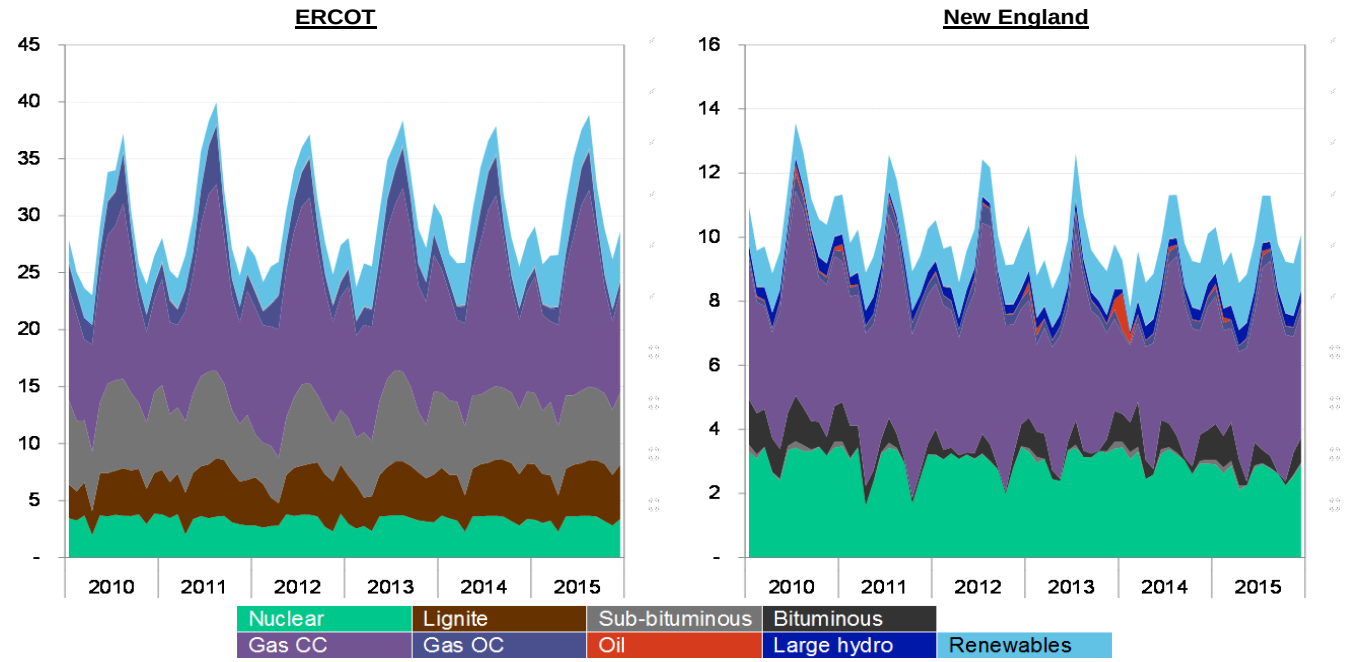
Monthly power mix in ERCOT and New England – 2010-15 (TWh/month)



The “Not-so-United” States Electricity System--Costs

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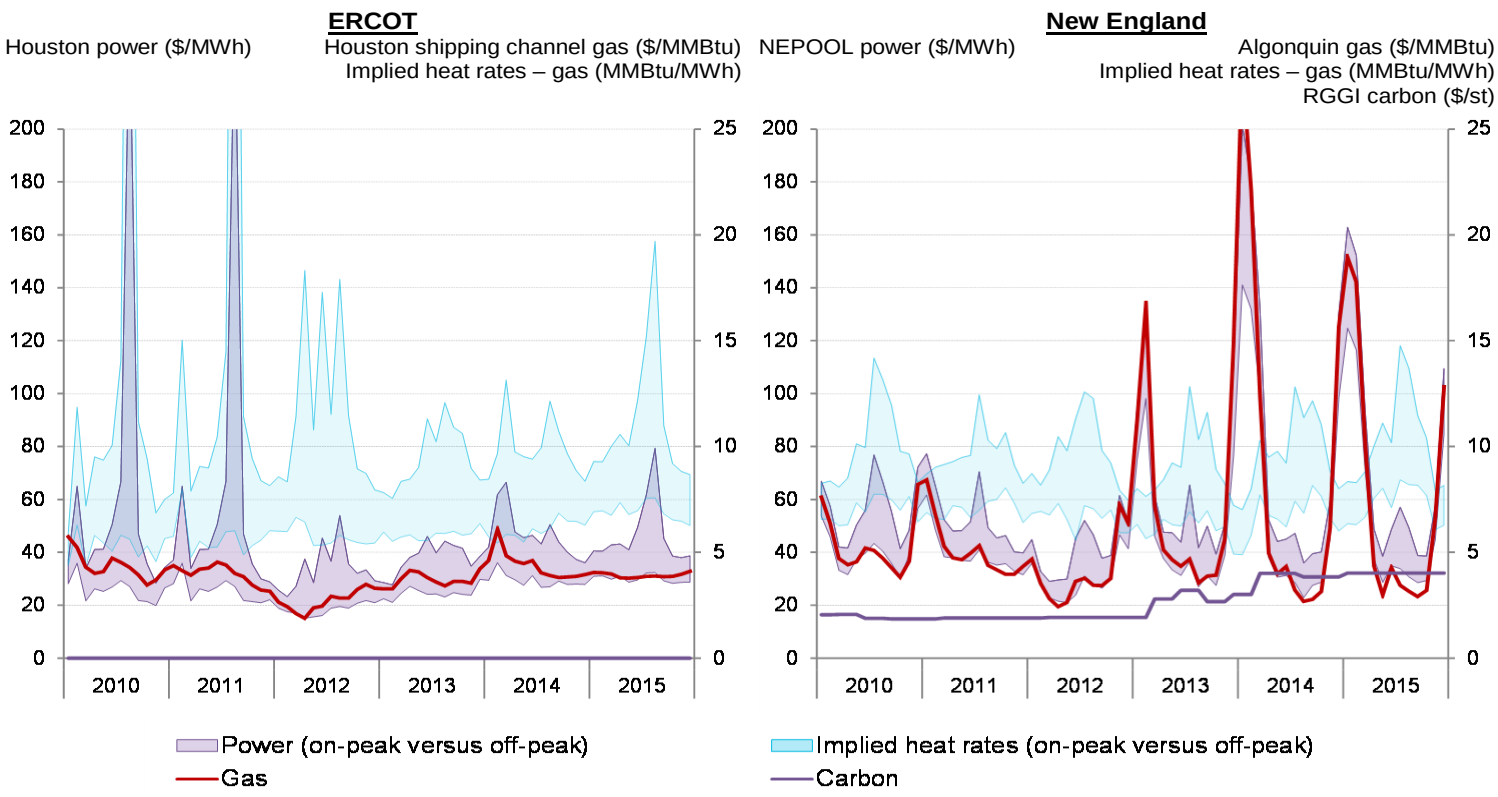
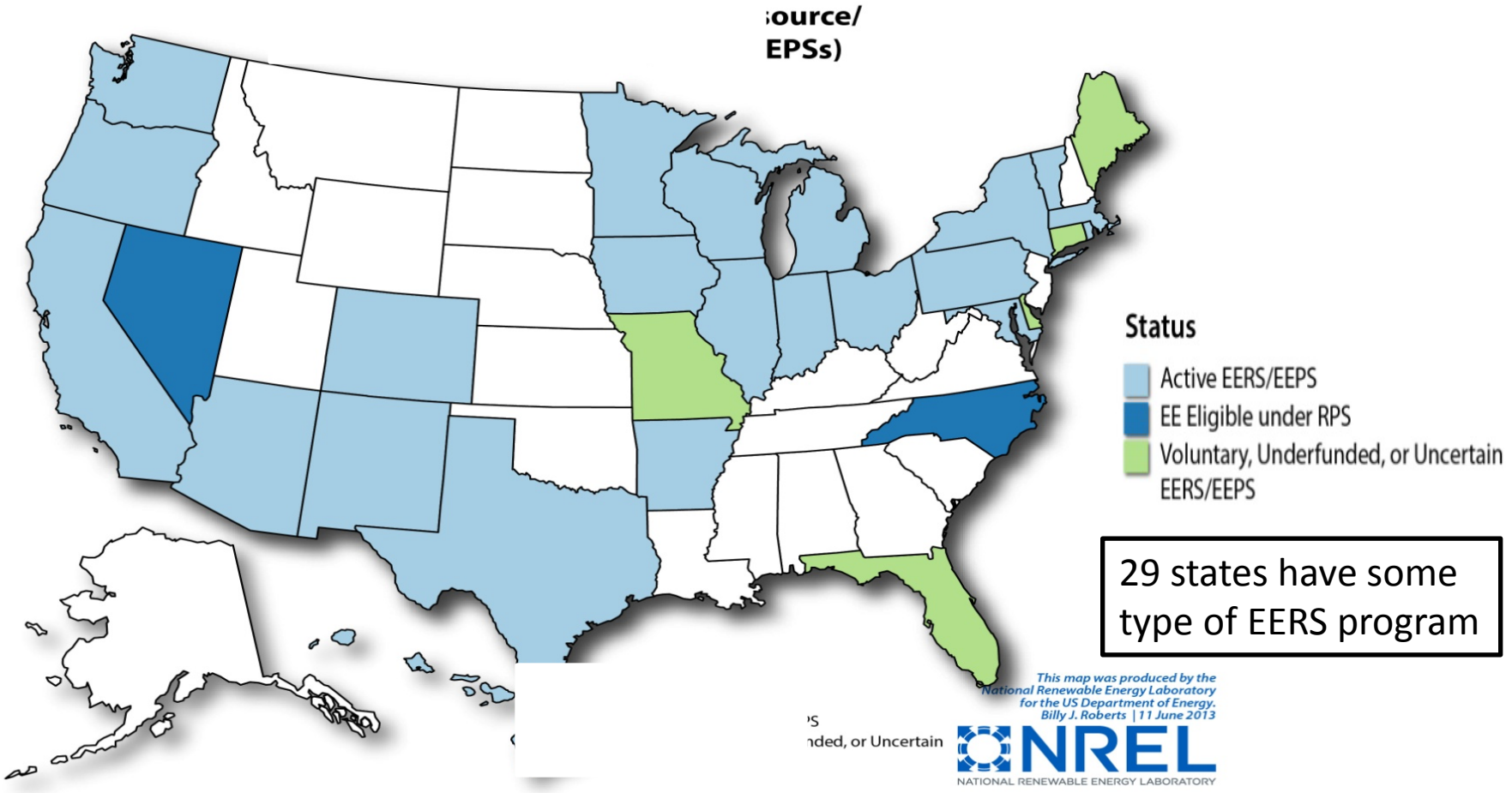
Monthly power prices in ERCOT and New England, 2010-15

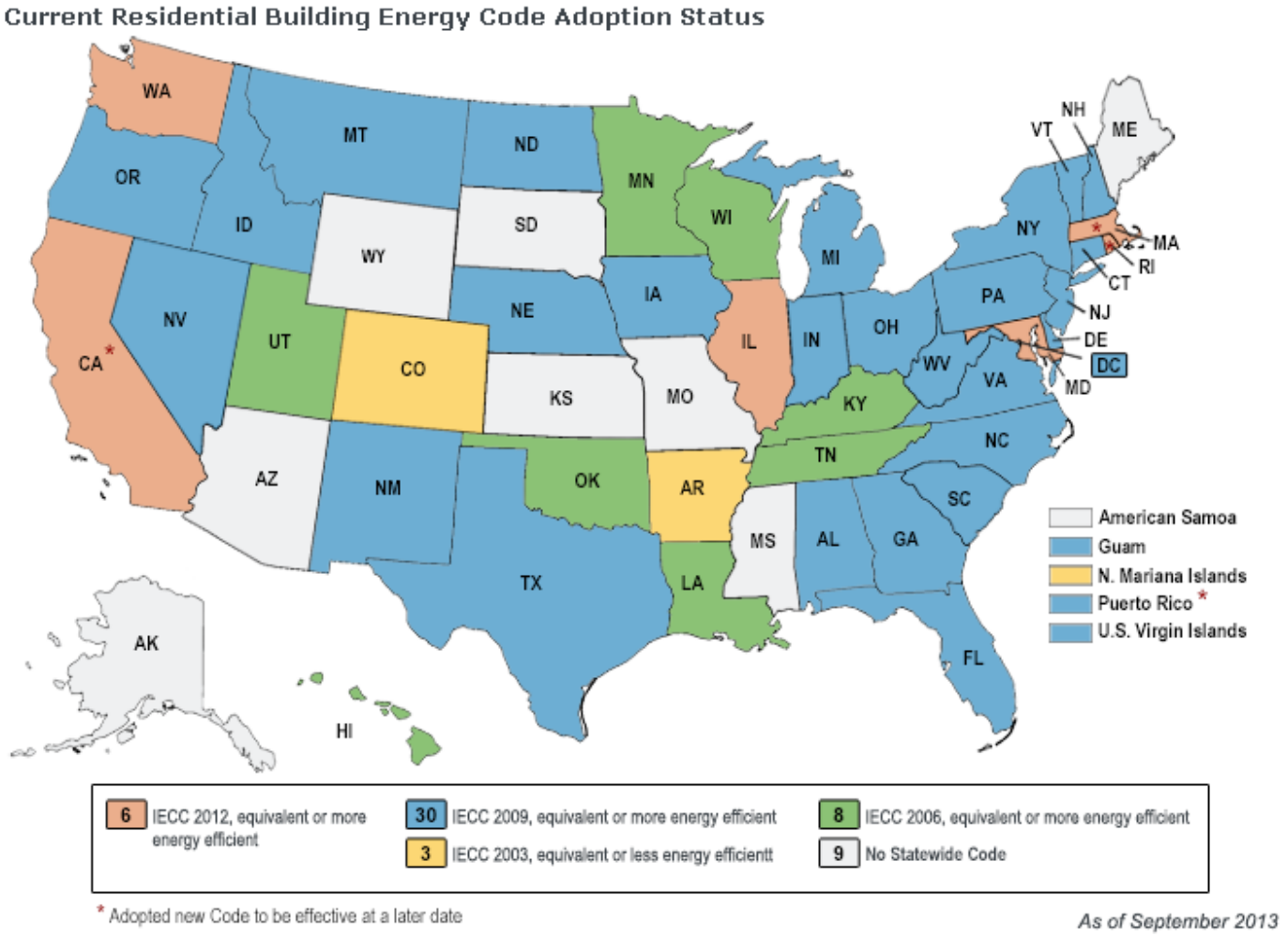


The “Not-so-United” States Electricity System--Efficiency



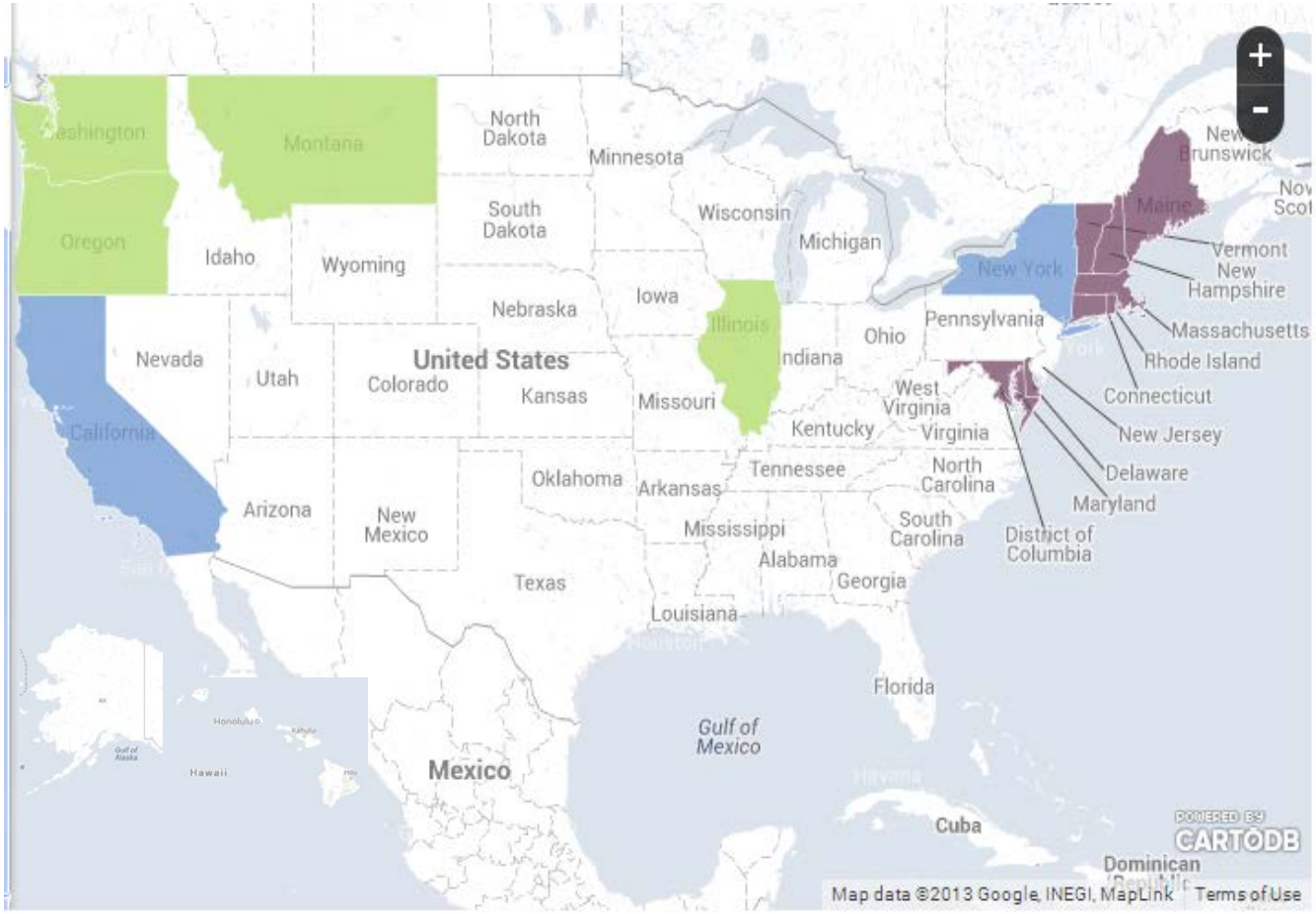
Ratepayer-funded EE programs aim to address barriers to cost-effective energy savings.

The “Not-so-United” States Electricity System-- Residential Building Codes



Source : DOE Building Technologies Program

The “Not-so-United” States Electricity System—Market Based Emission Policies and Performance Standards



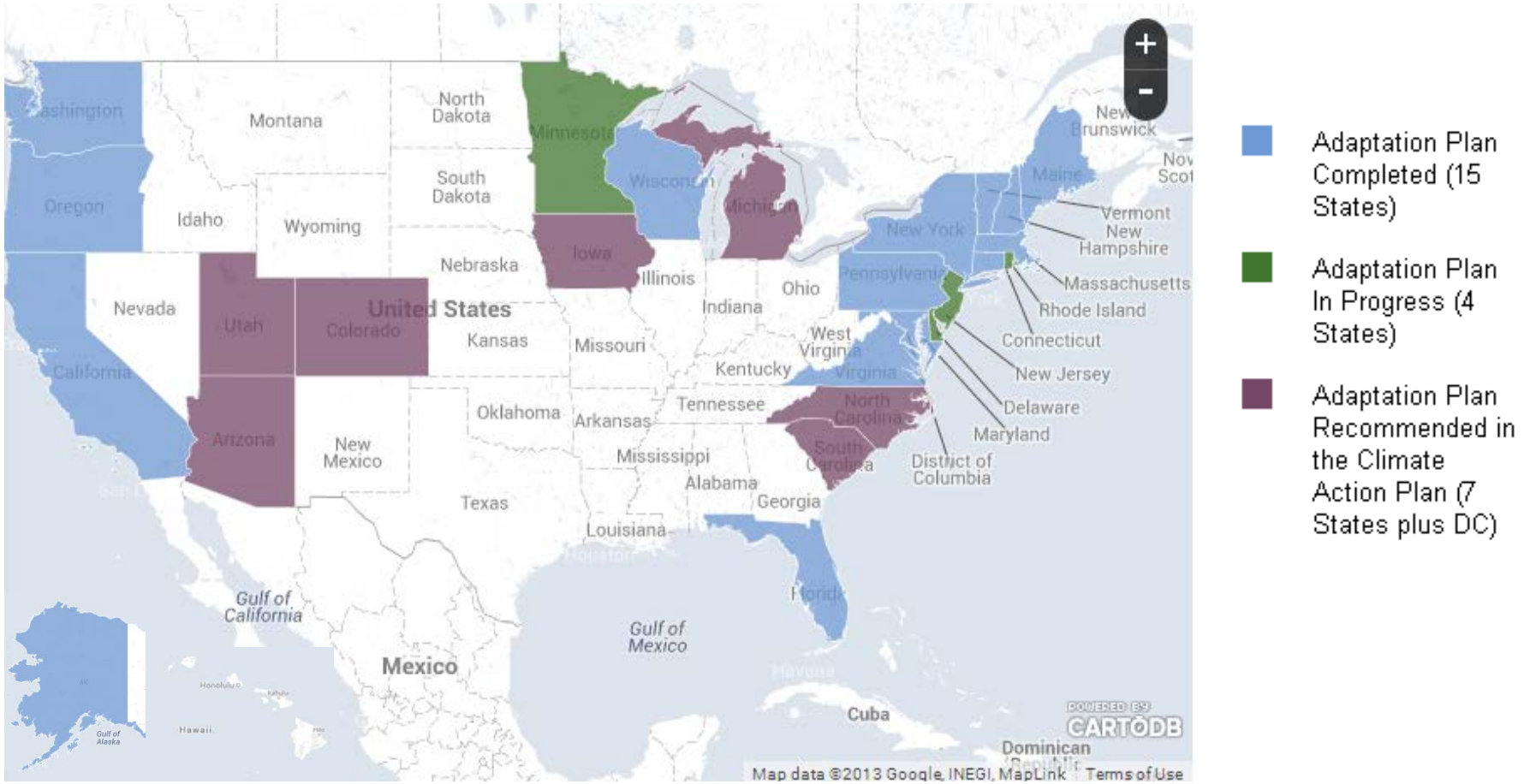
Emission Performance Standards

Utility Sector Cap and Trade

Emissions Standards and Cap and Trade

Source : C2ES. Accessed on 10/3/2013 http://www.c2es.org/us-states-regions

The “Not-so-United” States Electricity System--Adaptation

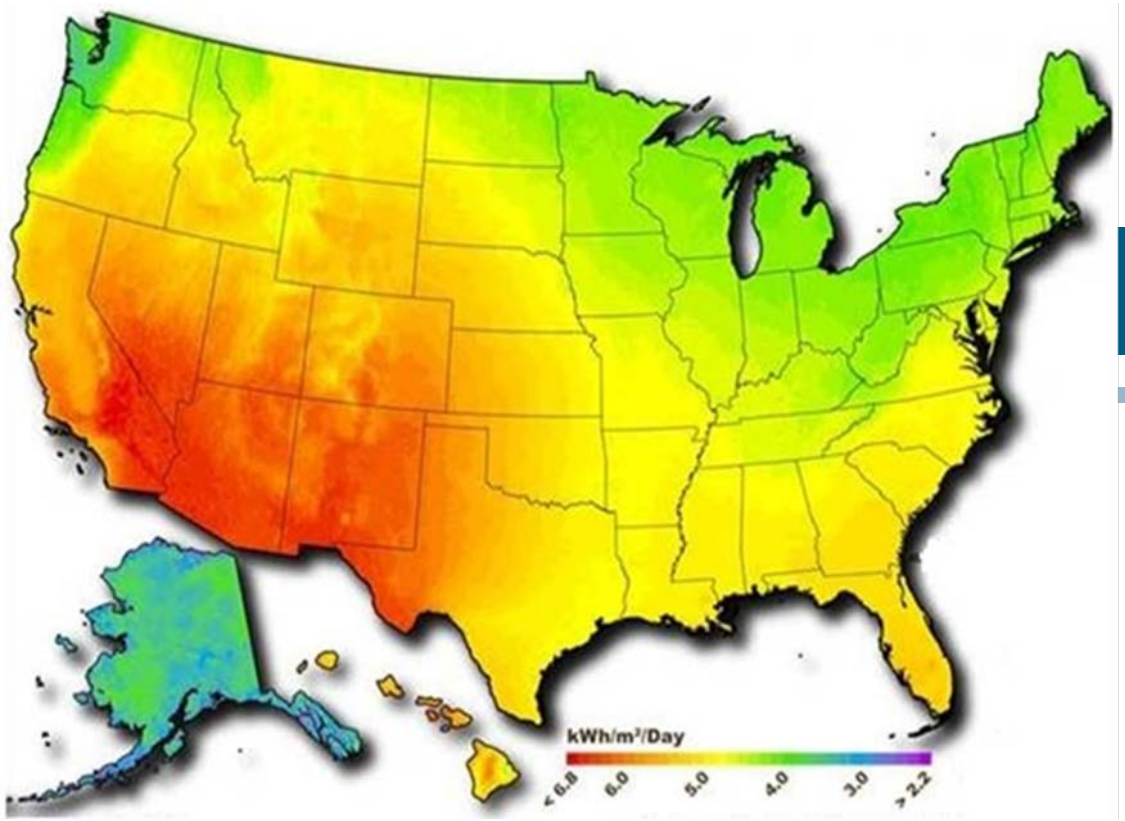


States are developing their own custom adaptation plans to prepare for location specific changes from climate change.

Source : C2ES. Accessed on 10/9/2013 http://www.c2es.org/us-states-regions

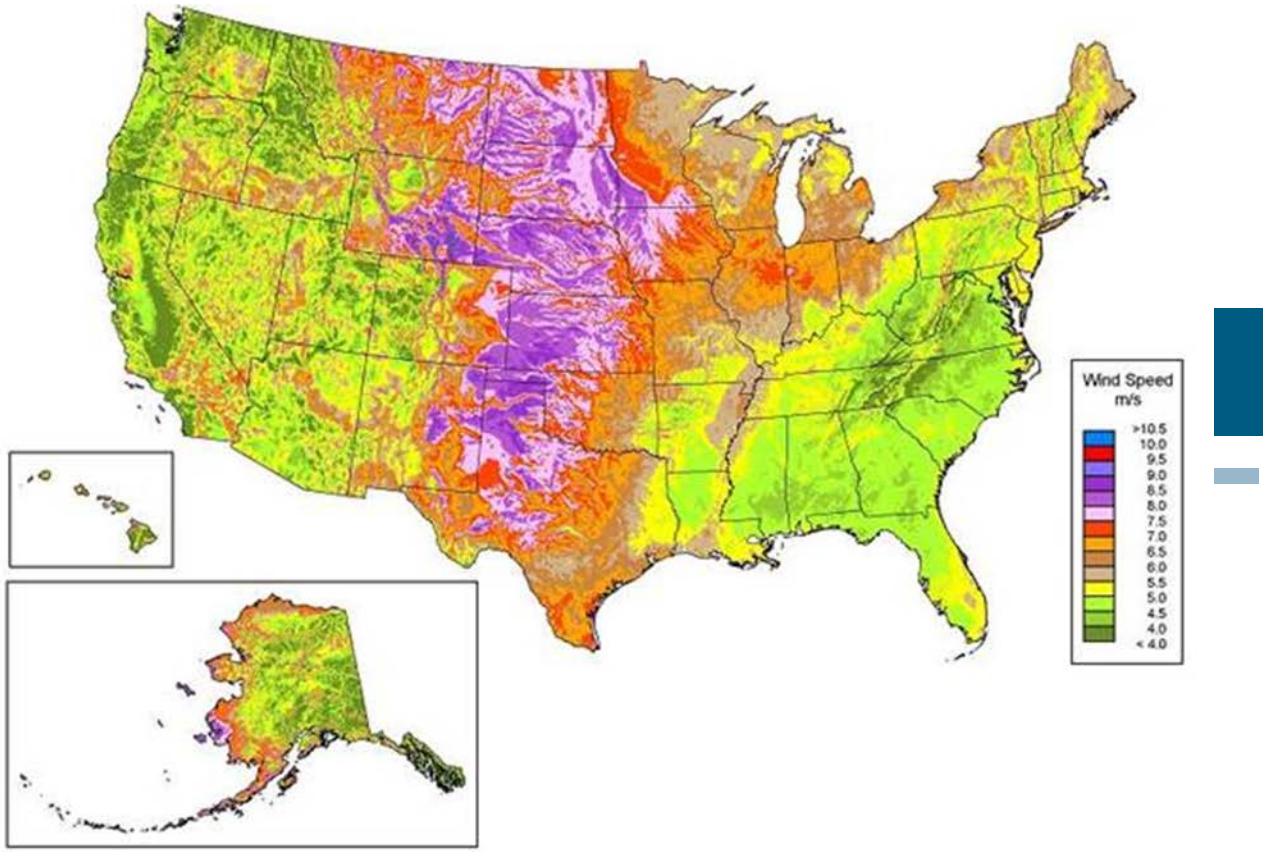
The “Not-so-United” States Electricity System—Solar Resources

Photovoltaic Solar Resource



Source: National Renewable Energy Laboratory. Online at http://www.nrel.gov/gis/solar.html

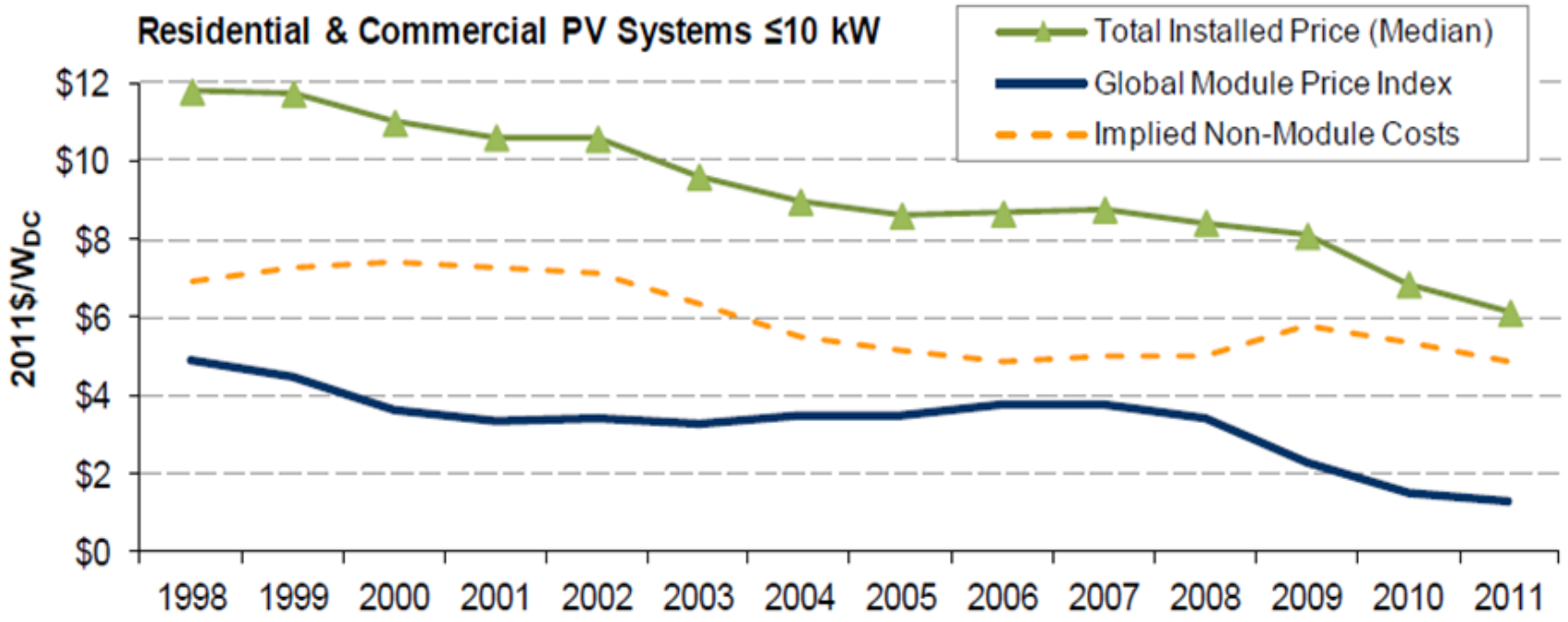
The “Not-so-United” States Electricity System–Wind Resources



Source: National Renewable Energy Laboratory. Online at http://www.nrel.gov/gis/images/80m_wind/USwind300dpe4-11.jpg

The "Not-so-United" States Electricity System-Renewable Policy vs. Costs

Residential and Commercial Solar Photovoltaic Costs



Source: Barbose, Galen, Naïm Darghouth, and Ryan Wiser, Tracking the Sun V: An Historical Summary of the Installed Price of Photovoltaics in the United States from 1998 to 2011, Lawrence Berkeley National Laboratory, November 2012, p. 14. Available at http://emp.lbl.gov/sites/all/files/lbnl-5919e.pdf.

The “Not-so-United” States Electricity System-Renewable Policy

Bloomberg NEW ENERGY FINANCE

Renewable energy generation and RPS demand by region, 2002-30 (TWh)