JISEA Joint Institute for Strategic Energy Analysis

Natural Gas and Power Sector Decarbonization Pathways: Three Snapshots from Recent JISEA Research

Jeffrey Logan, Wesley Cole, and Jacquelyn Pless

April 13, 2016

NREL NATIONAL RENEWABLE ENERGY LABORATORY · COLORADOSCHOOLOFMINES · Colorado State University · Massachusetts Institute of Technology · STANFORD UNIVERSITY · University of Colorado Boulder

Presenters

Jeffrey Logan has over 20 years of experience in energy analysis, project management, and strategic planning. He specializes in energy policy analysis, low-carbon energy market development, greenhouse gas abatement, and energy security. At the National Renewable Energy Laboratory (NREL) since 2008, he currently leads a group of 25 analysts focusing mainly on strategic electric power policy issues. He leads novel work at NREL on the impacts of unconventional natural gas on energy markets, including renewables.

Wesley Cole is an energy system modeler and analyst in the Strategic Energy Analysis Center at NREL. He specializes in dynamic and steady-state modeling of energy systems, optimization and advanced control of energy systems, and integrated energy system analysis. His primary research interests include interactions of the natural gas supply chain with the deployment of renewable energy technologies.

Jacquelyn Pless is a research economist at the Joint Institute for Strategic Energy Analysis (JISEA). Her research combines empirical evidence and economic theory in the areas of energy and environmental economics, public economics, and behavioral economics to help inform the design of effective policy and business strategy and improve quality of life.

JISEA Joint Institute for Strategic Energy Analysis

Regional and Sectoral Trends in U.S. Electricity Markets: Focus on Natural Gas

Jeffrey Logan

April 13, 2016

NREL NATIONAL RENEWABLE ENERGY LABORATORY · COLORADOSCHOOLOFMINES · Colorado State University · Massachusetts Institute of Technology · STANFORD UNIVERSITY · University of Colorado Boulder

Outline

- National Trends
- Regional Trends by NERC Region
- Sectoral Trends

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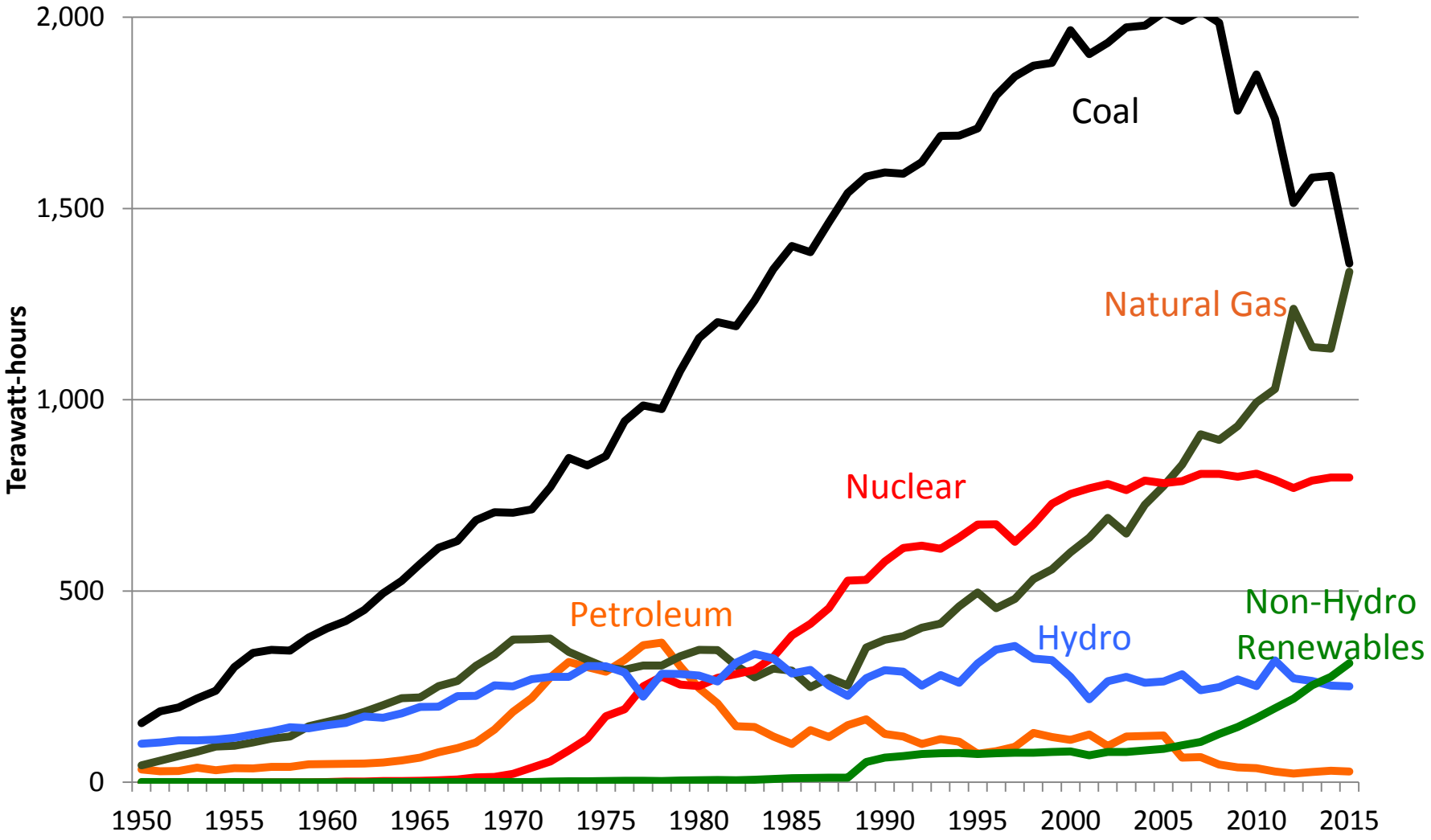
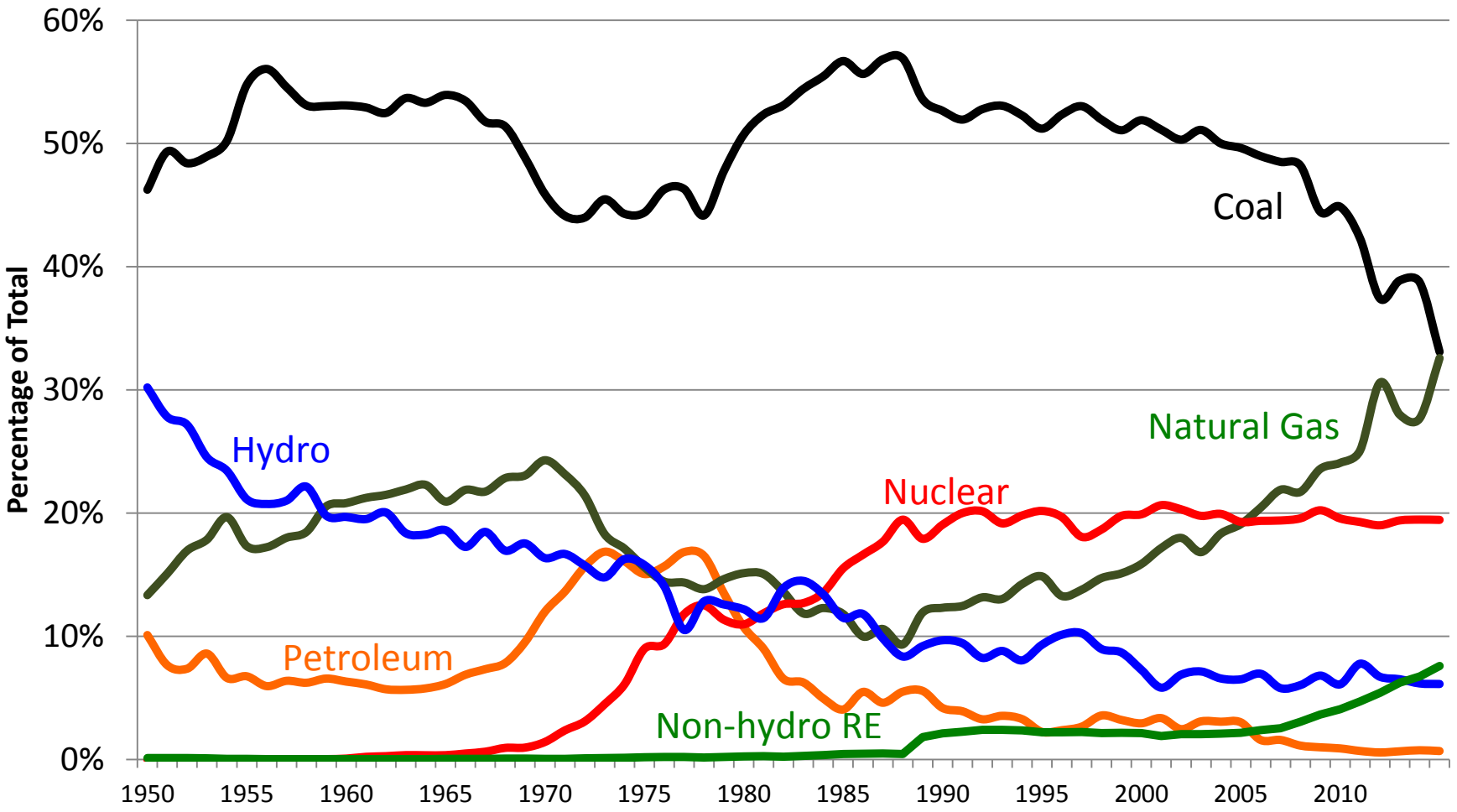
U.S. Generation by Fuel Type



The U.S. Power Sector Is Undergoing Profound Transformation

Source: Electric Power Monthly, EIA.

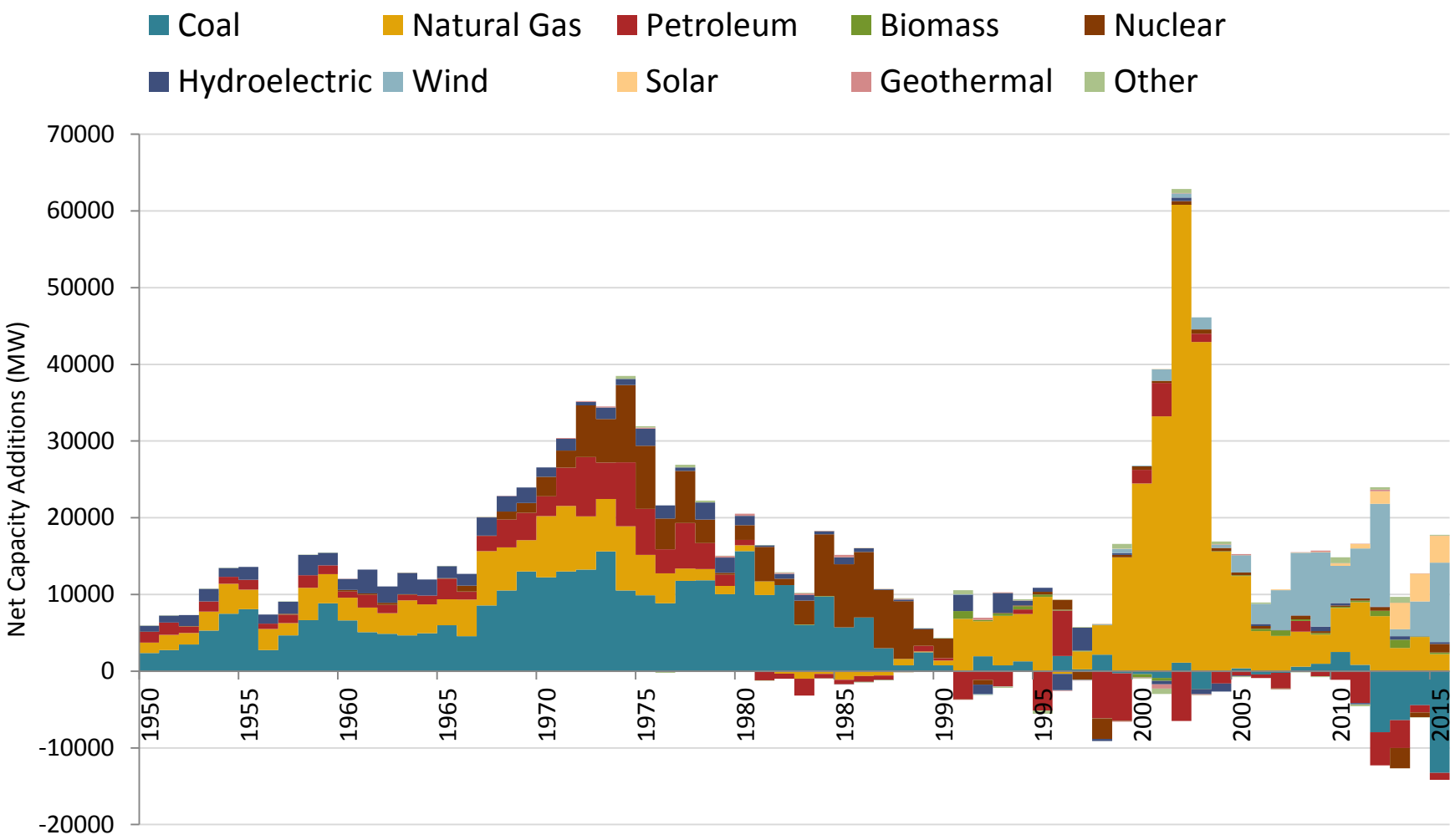
Generation Shares



Coal, Natural Gas And Non-hydro Renewables Are The Most Dynamic

Source: Electric Power Monthly, EIA.

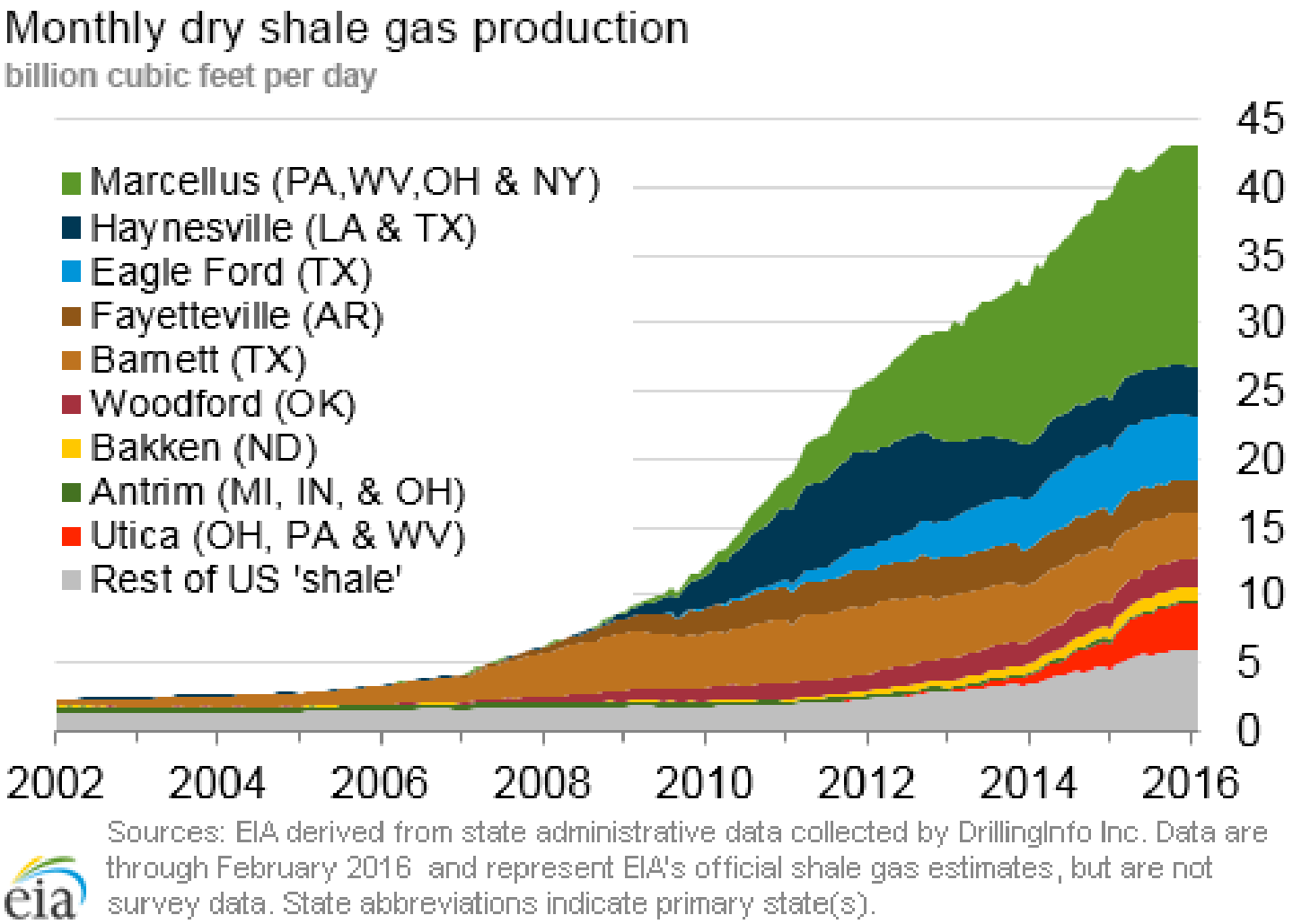
Net Capacity Additions by Fuel Type



Nearly 35 GW of Coal Retired in Past 4 Years

Source: EIA.

U.S. Shale Production



Shale Gas Supplied 58% of Total Dry Natural Gas Production in 2015

Source: Natural Gas Weekly Update, EIA.

Outline

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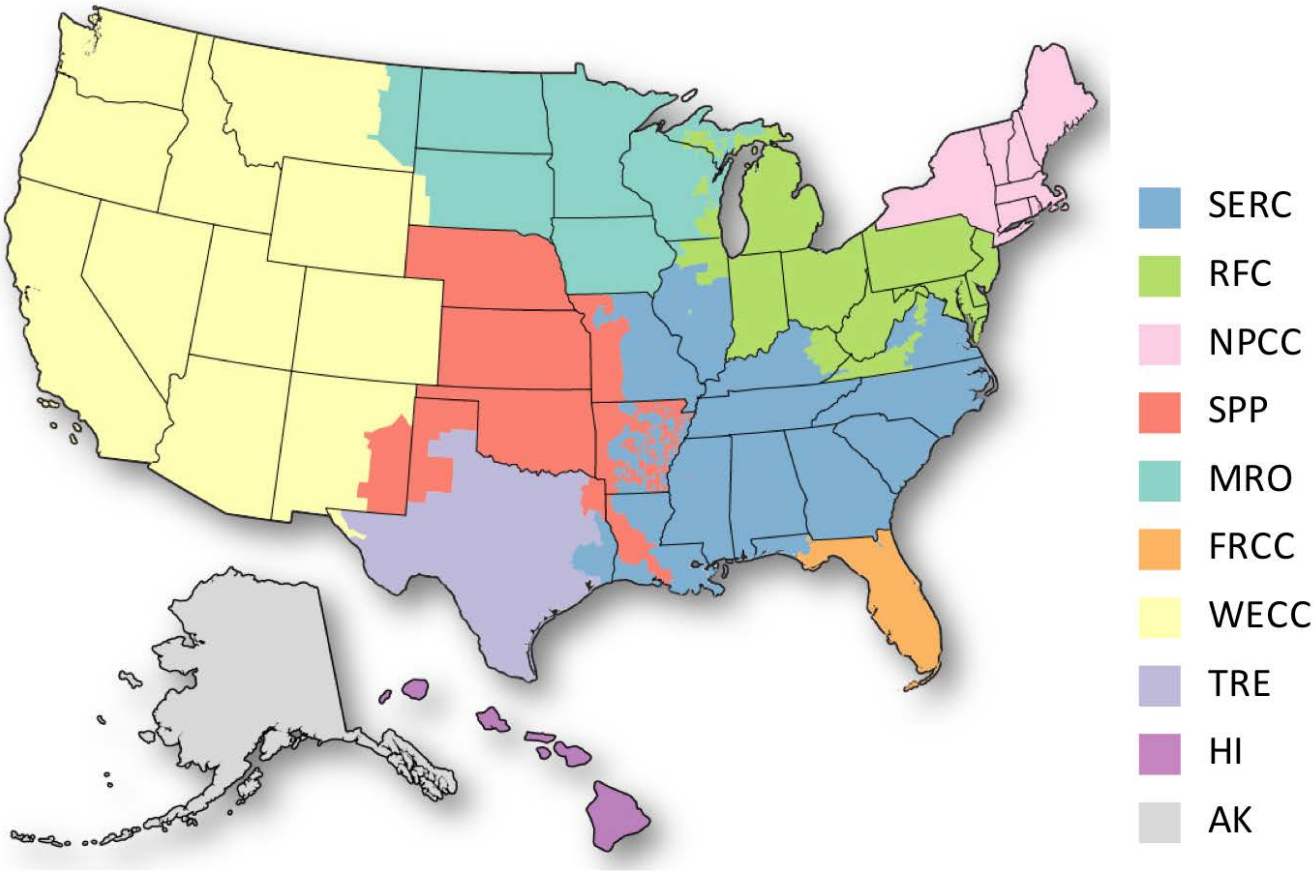
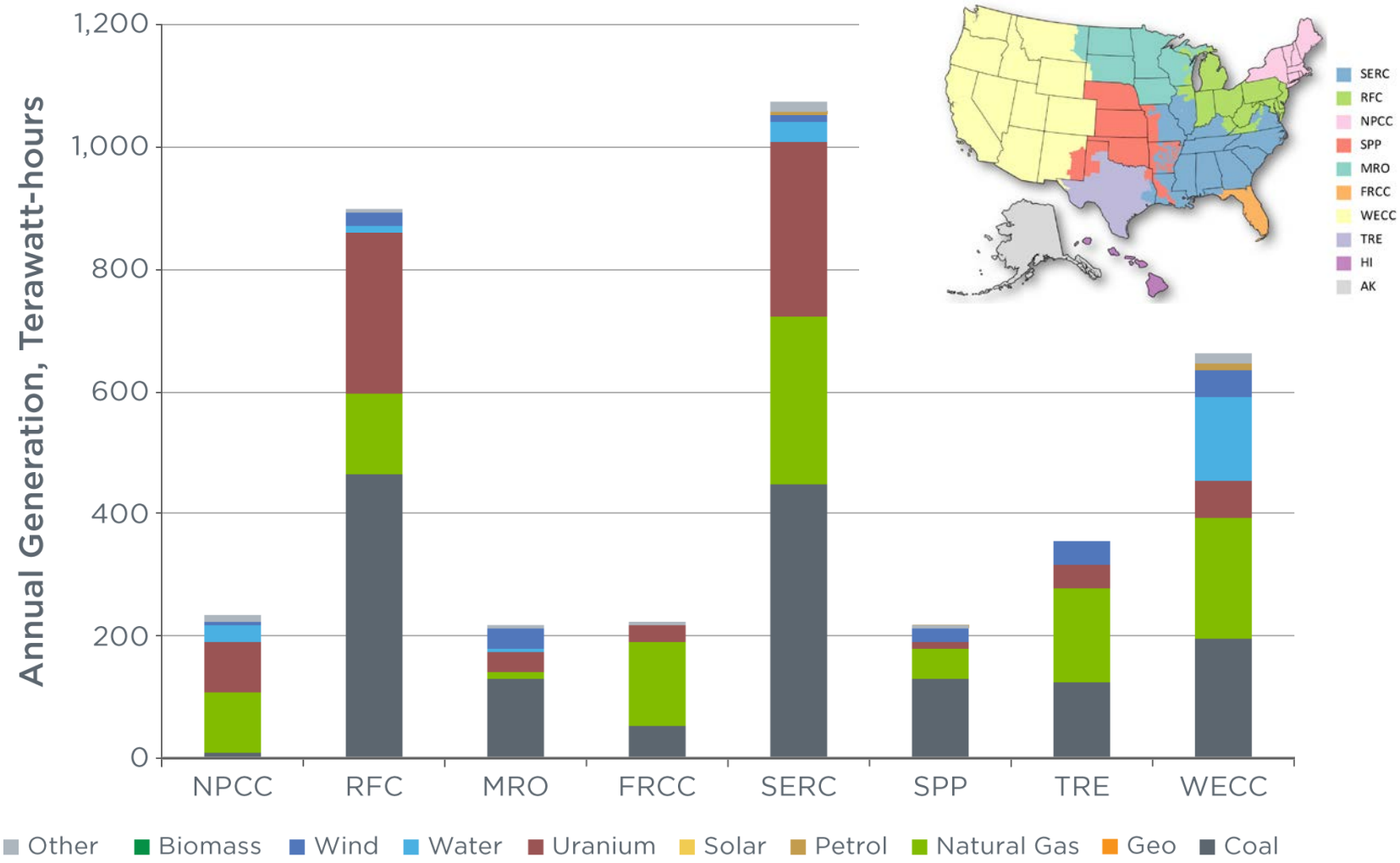
- Sectoral Trends

Map of Reliability Organizations



Generation Mix By Region

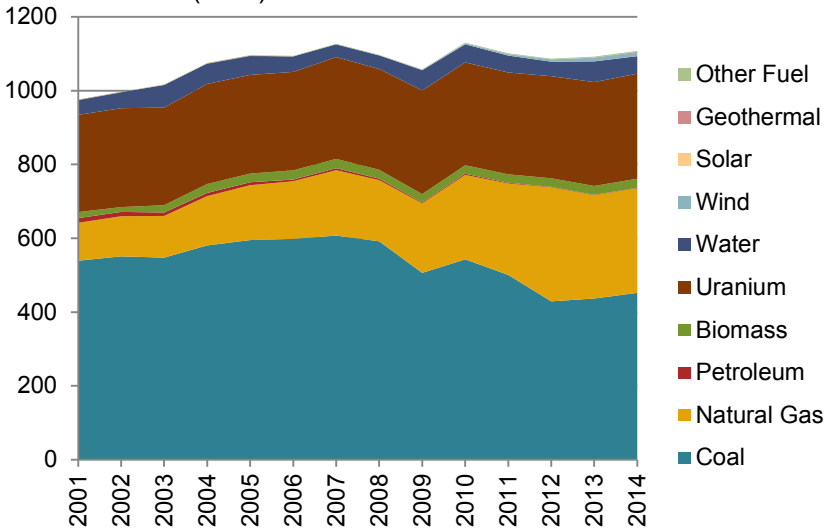


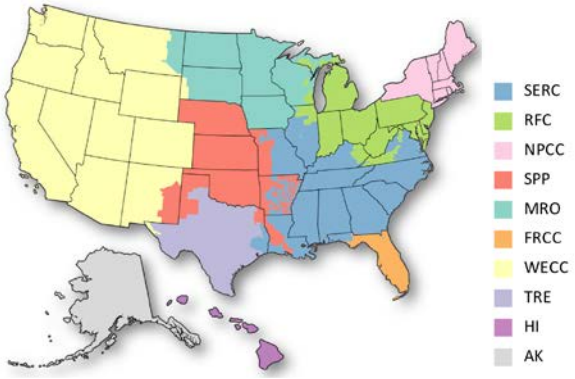
Northeast, Florida and Texas Dominated by NG; Midwest and Southeast by Coal

Source: SNL Financial.

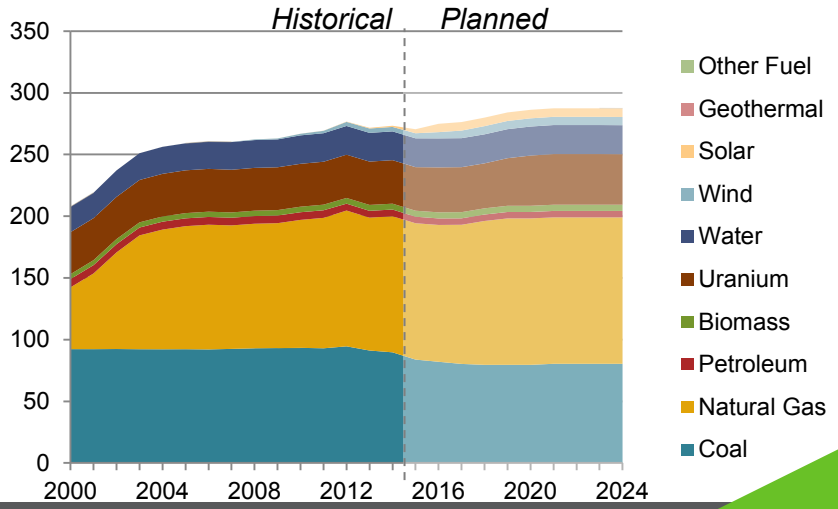
Southeast Region

SERC Annual Generation by Fuel
Terawatt-hours (TWh)





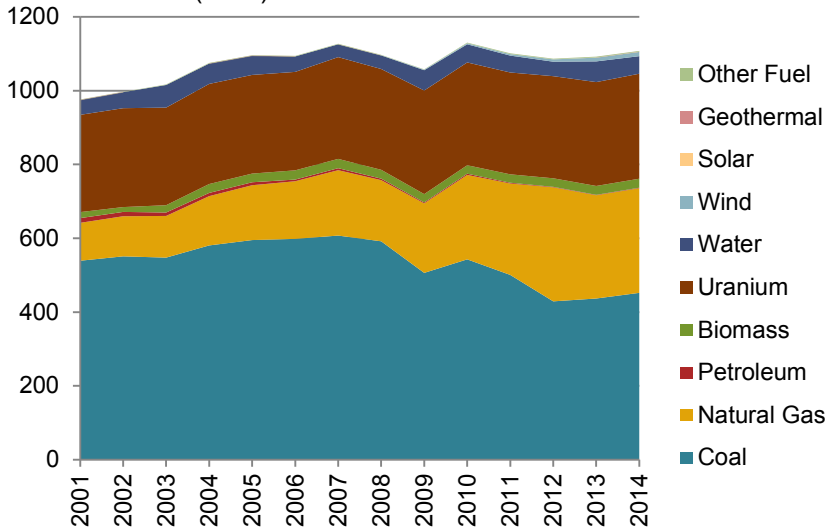
SERC Capacity by Fuel
gigawatts (GW)



Source: SNL Financial.

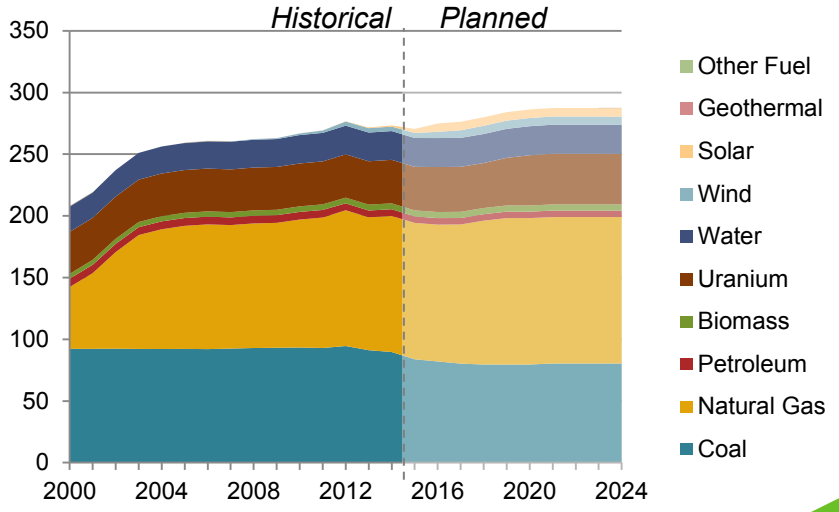
Southeast Region

SERC Annual Generation by Fuel
Terawatt-hours (TWh)



2009-2014
Coal Generation: -11%
NG Generation: +51%
Non-hydro RE: +52%
Total Demand: +5%

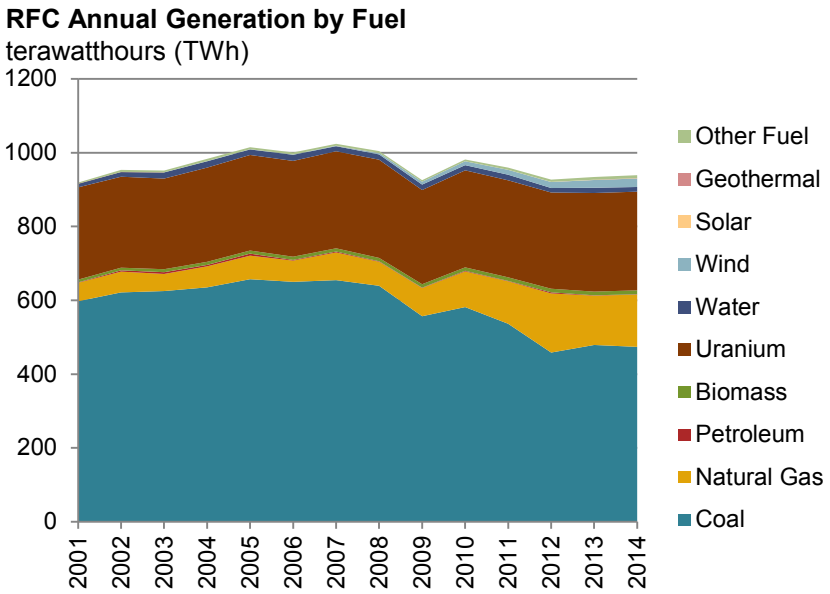
SERC Capacity by Fuel
gigawatts (GW)

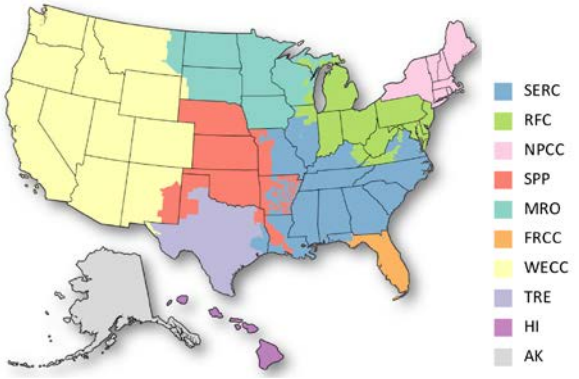


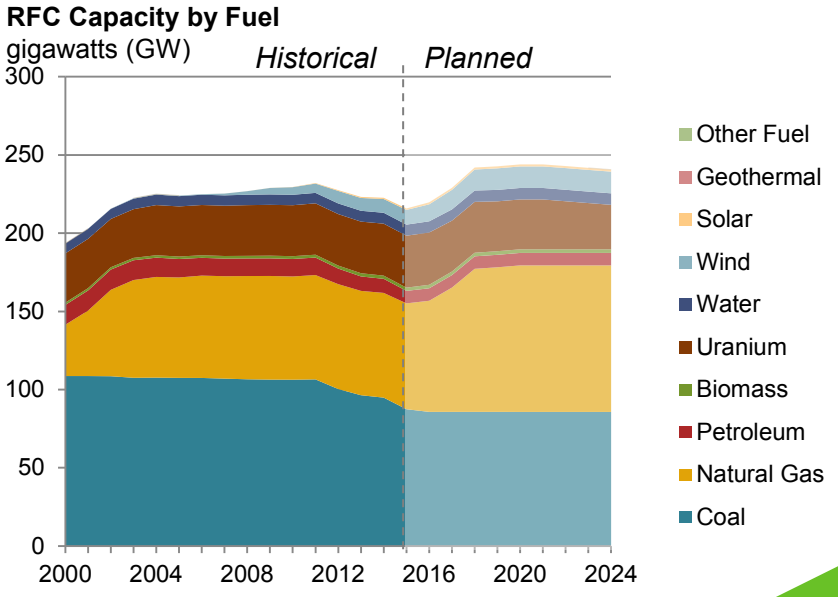
Coal Dominant, But Declining
Strong Growth in NG Generation
Only Region with New Nuclear Coming
RE Growing Strongly But From Very Low Base

Source: SNL Financial.

Reliability First Region

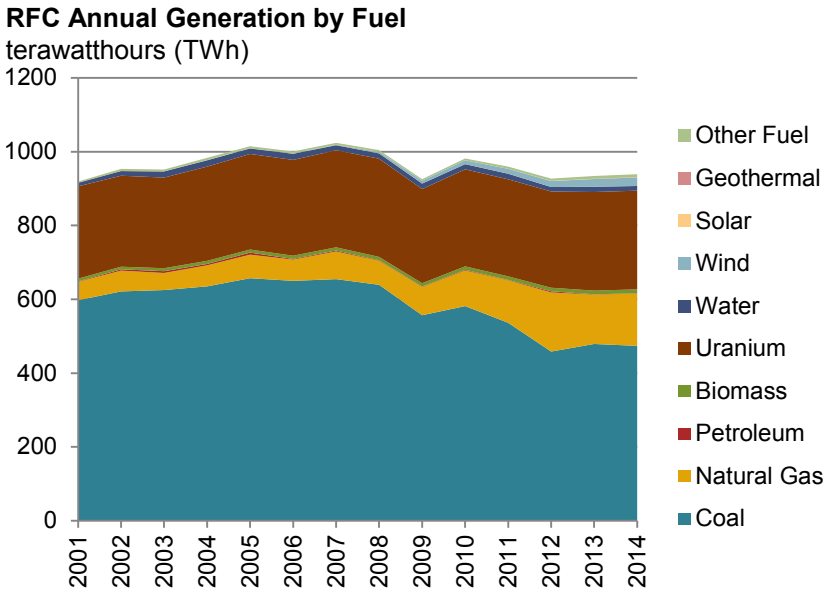




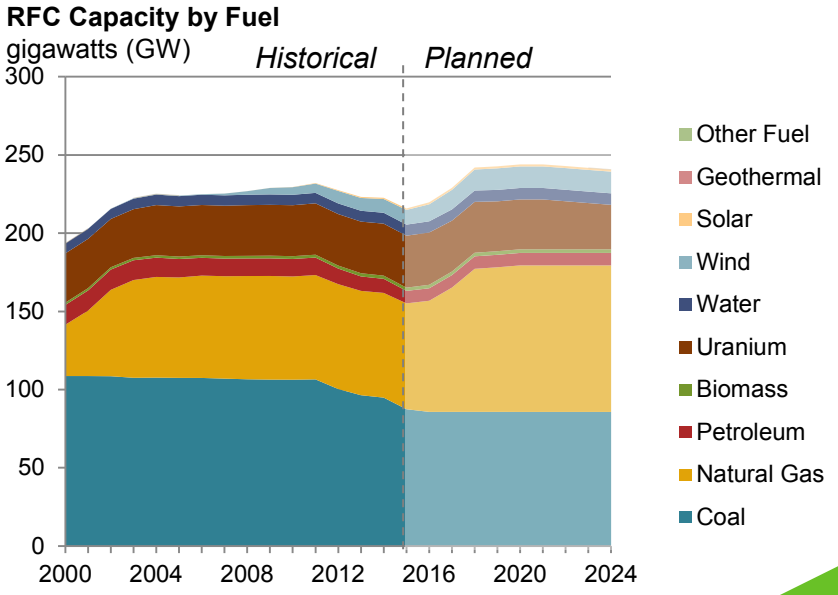


Source: SNL Financial.

Reliability First Region



2009-2014
Coal Generation: -15%
NG Generation: +85%
Non-hydro RE: +102%
Total Demand: +1%

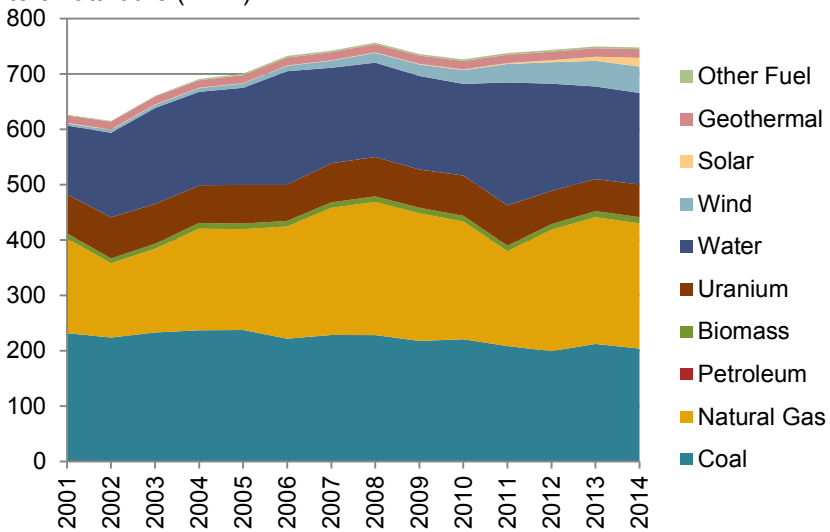


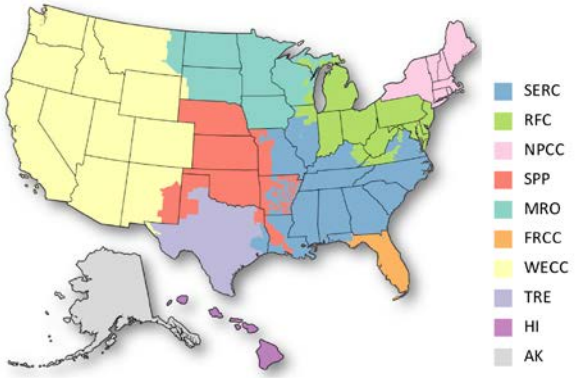
Remains Coal Dominant
But Strong Coal to NG Re-dispatch
Strong Wind Power Growth From Low Base
Flat Demand Growth

Source: SNL Financial.

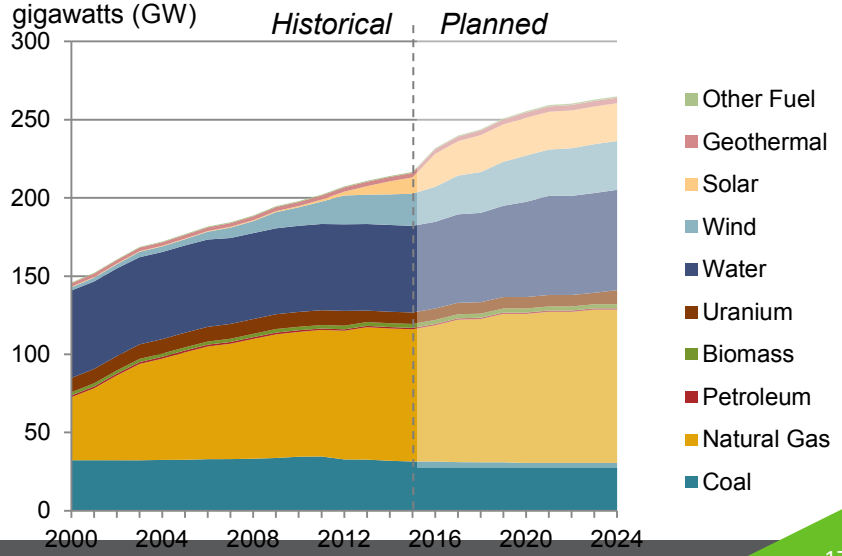
Western Region

WECC Annual Generation by Fuel
terawatthours (TWh)



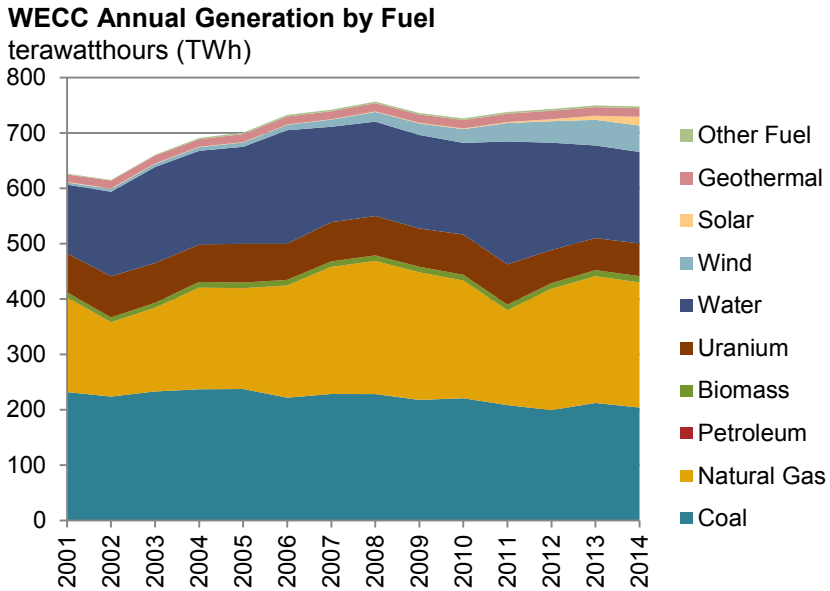


WECC Capacity by Fuel
gigawatts (GW)

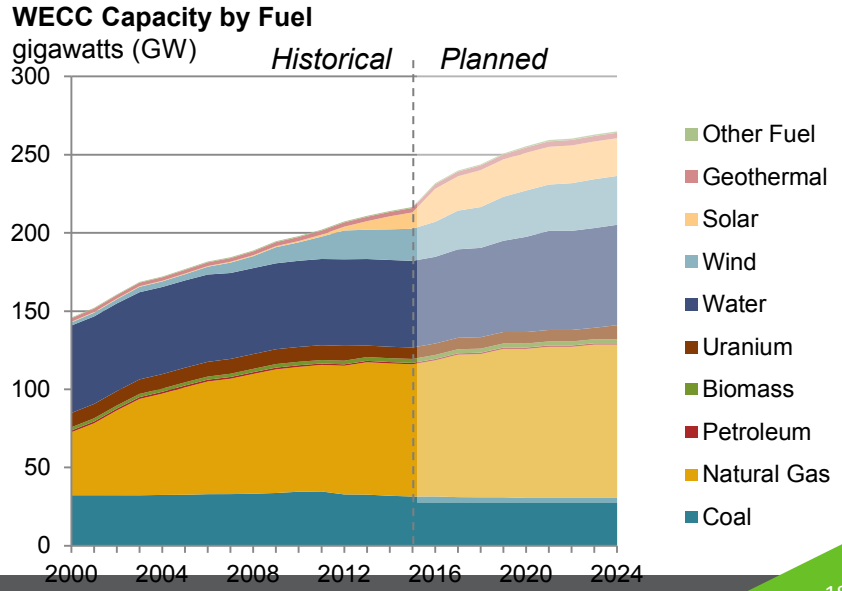


Source: SNL Financial.

Western Region



2009-2014
Coal Generation: -6%
NG Generation: -2%
Non-hydro RE: +92%
Total Demand: +2%



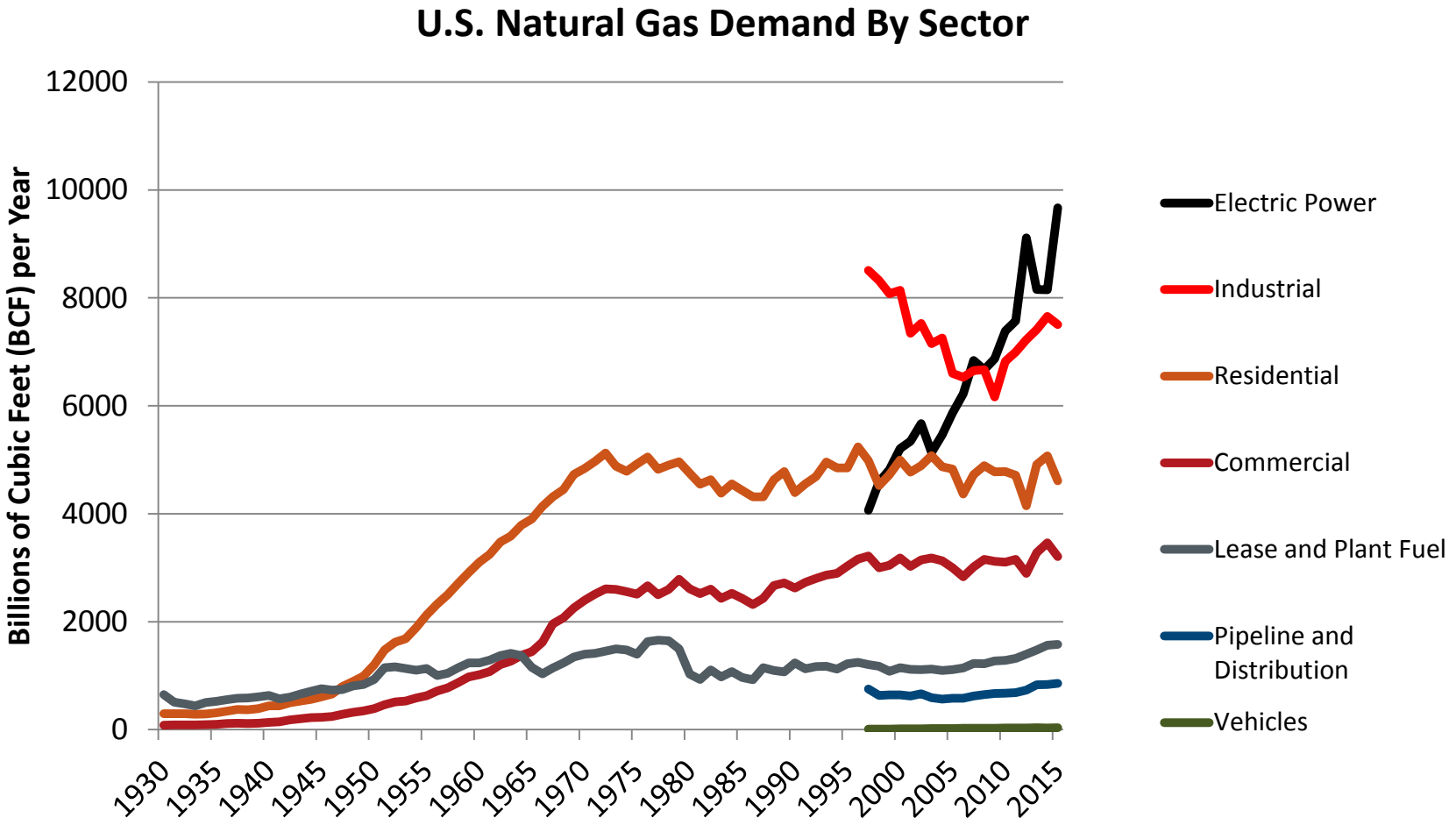
Declining Coal and Gas Generation
Strong Growth in RE, Especially Solar
Flat Demand Growth

Source: SNL Financial.

Outline

- National Trends
- Regional Trends by NERC Region
- Sectoral Trends

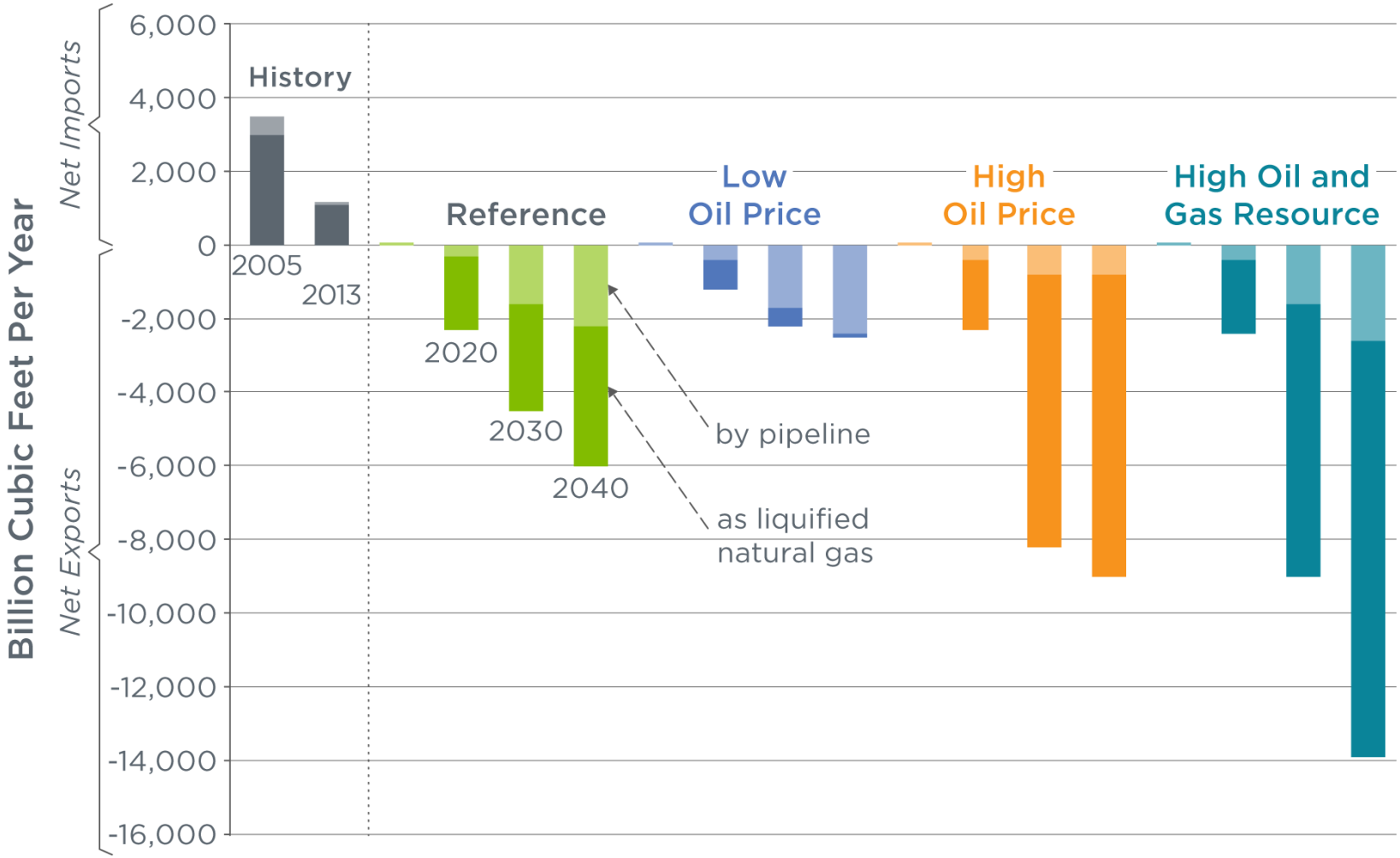
U.S. Natural Gas Demand by Sector



Industrial Gas Demand Has Rebounded Since 2010, but Electric Power Demand Growth is Strongest

Source: EIA.

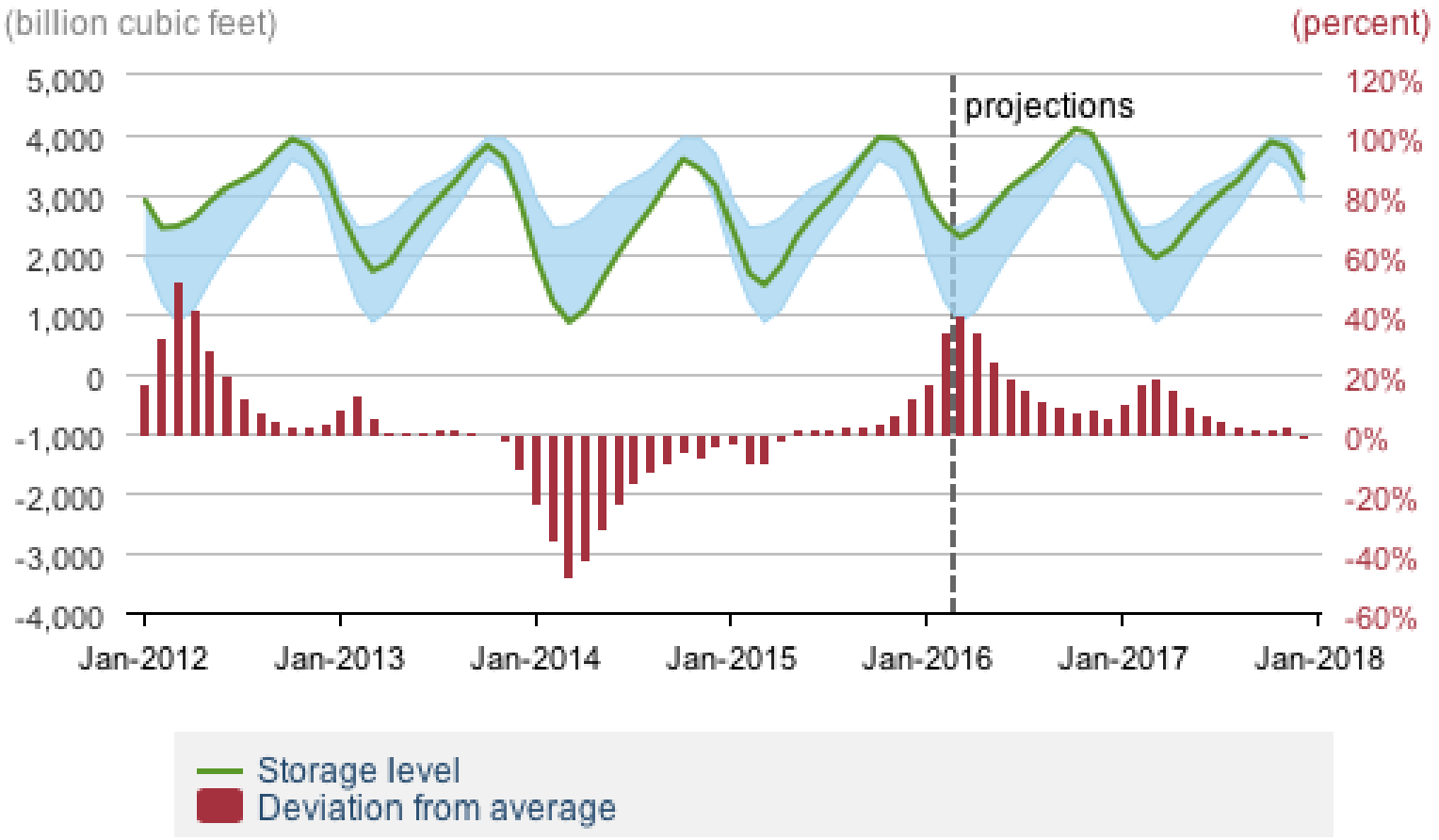
U.S. Net Natural Gas Trade



U.S. Expected To Become Significant Gas Exporter By 2020

Source: Annual Energy Outlook, EIA.

NG Storage Outlook



High Projected Storage Levels Will Keep Downward Pressure on Prices

Source: Short Term Energy Outlook, EIA.

Conclusions

- Significant shift from coal to natural gas generation occurring, mainly in eastern half of country (re-dispatch mostly)
- Strong growth in wind and solar generation, especially in western half of country, but growing everywhere
- Modest rebound in overall industrial NG demand
- Publication available here:

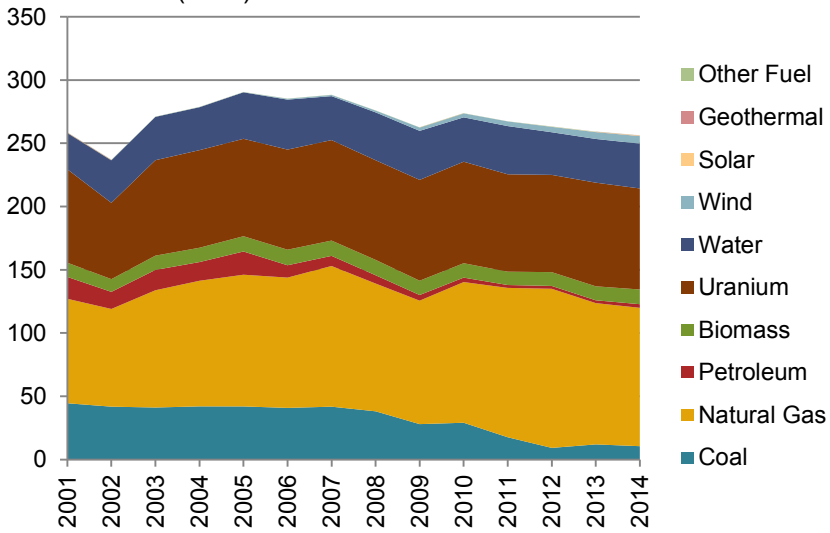
http://www.nrel.gov/docs/fy16osti/64652.pdf

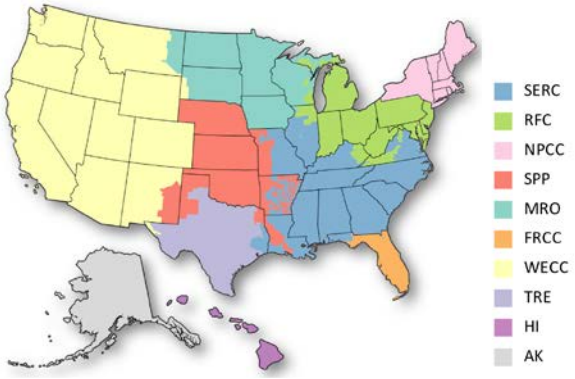
Additional Regional Slides

- Northeast
- Midwest
- Florida
- Southwest
- Texas

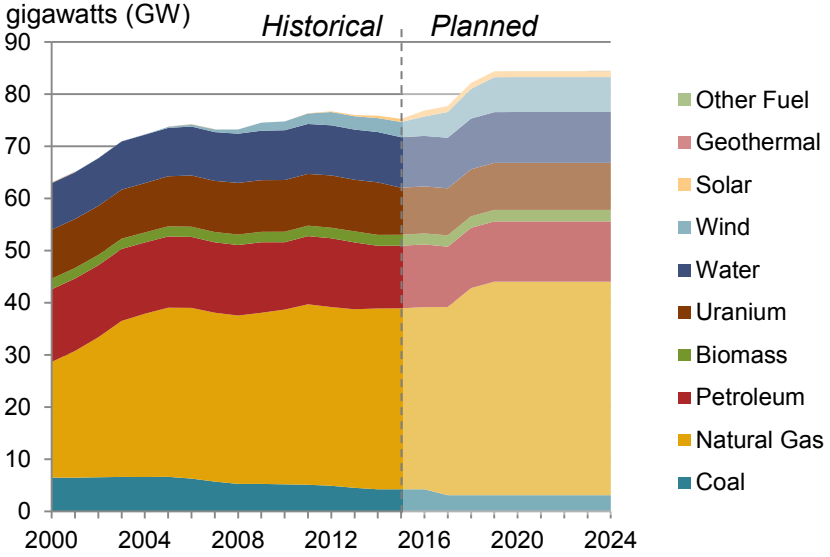
Northeast Region

NPCC Annual Generation by Fuel
terawatthours (TWh)



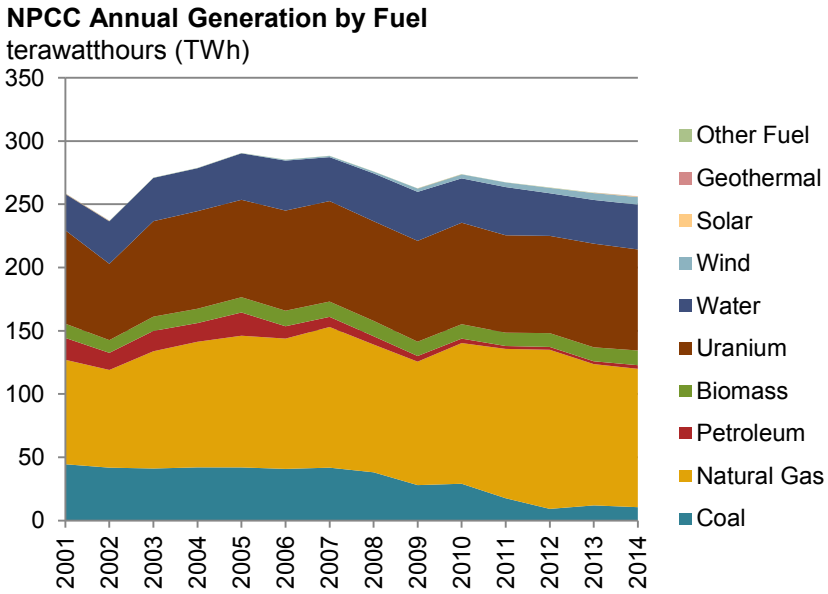


NPCC Capacity by Fuel
gigawatts (GW)

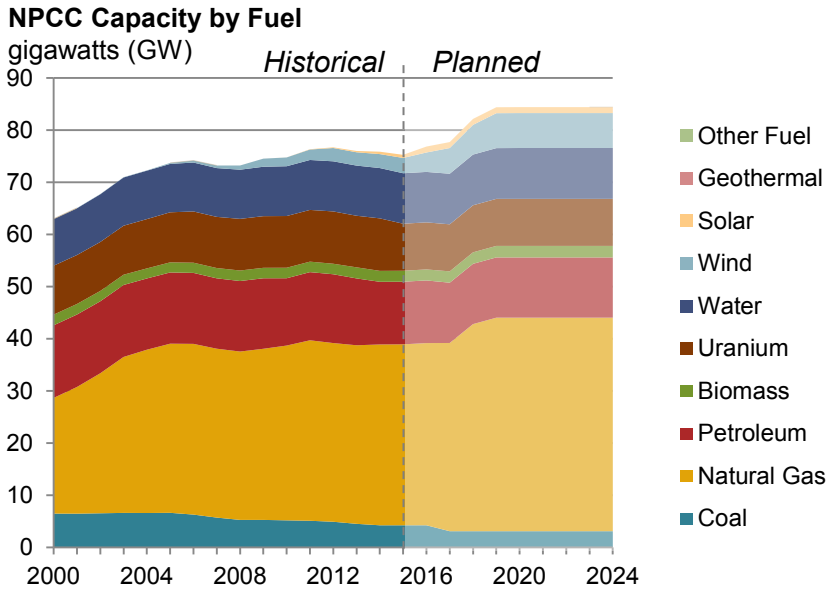


Source: SNL Financial.

Northeast Region



2009-2014
Coal Generation: -62%
NG Generation: +12%
Non-hydro RE: +148%
Total Demand: -2%

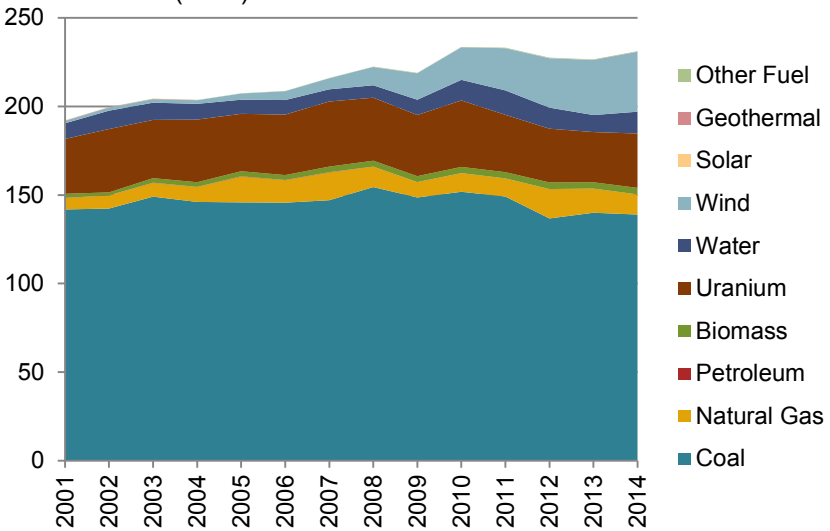


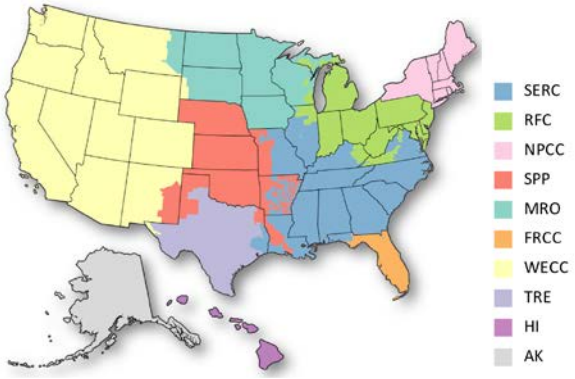
Becoming Increasingly Reliant on NG
Petroleum Gen Small But Important in Winter
Coal Nearly Gone
RE Growing Strongly But From Low Base
Demand Down from 2005 Peak

Source: SNL Financial.

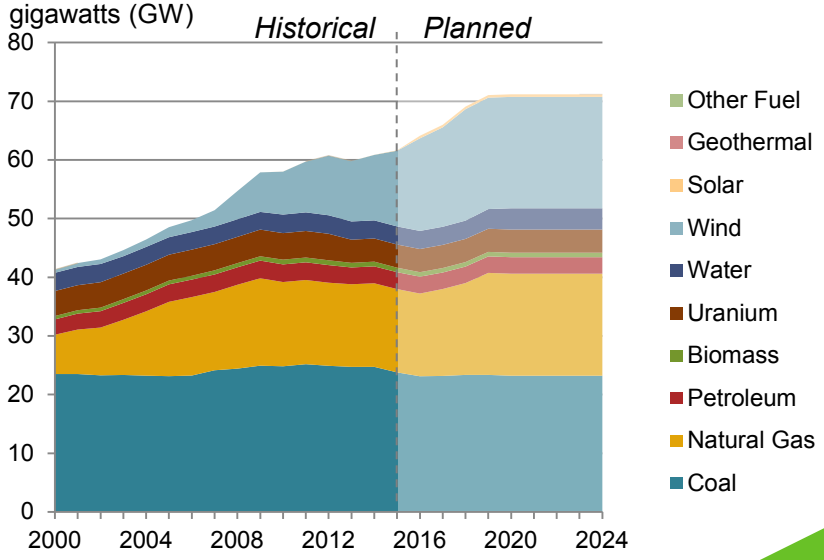
Midwest Region

MRO Annual Generation by Fuel
terawatthours (TWh)



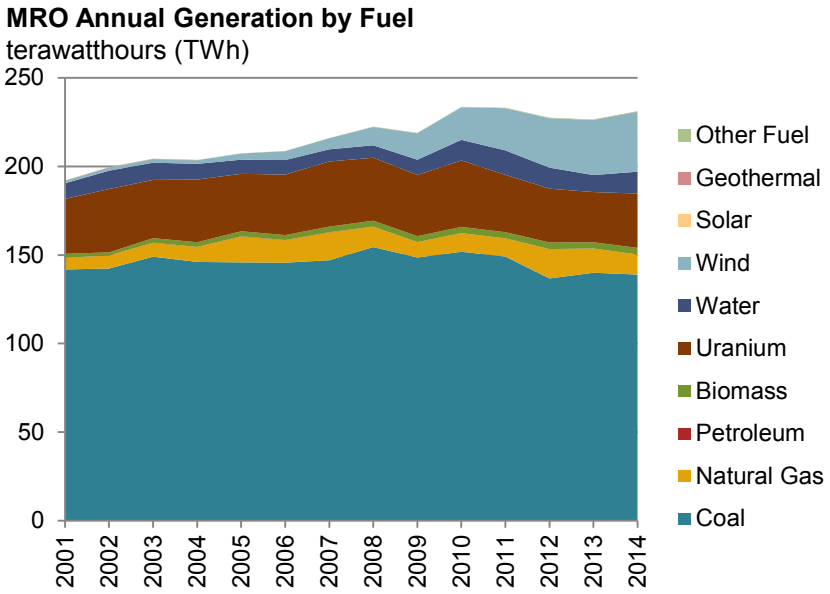


MRO Capacity by Fuel
gigawatts (GW)

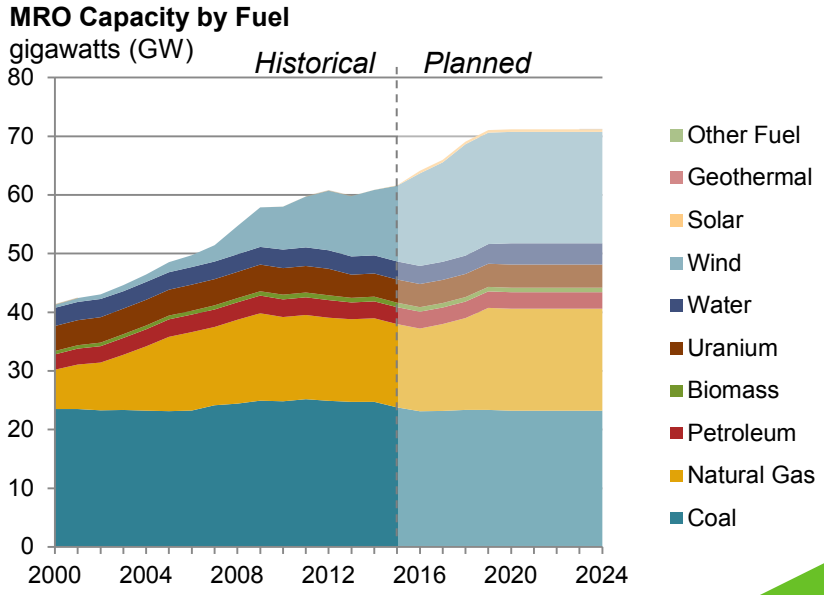


Source: SNL Financial.

Midwest Region



2009-2014
Coal Generation: -6%
NG Generation: +31%
Non-hydro RE: +105%
Total Demand: +6%

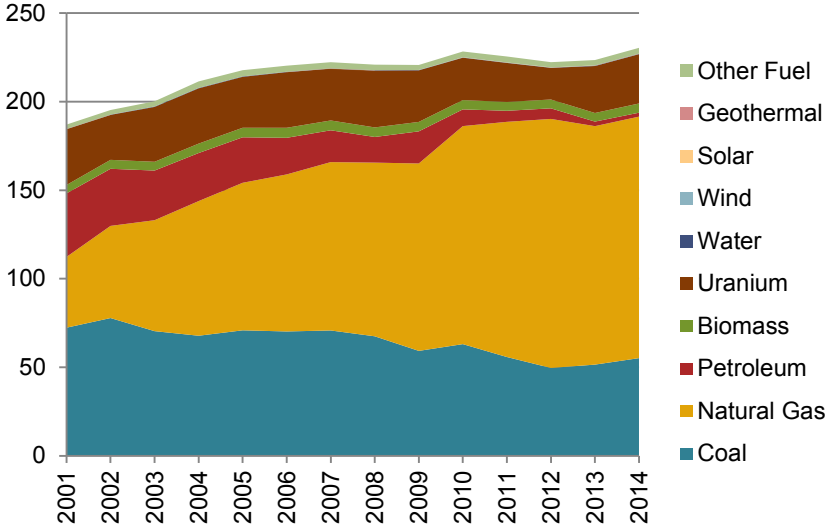


Remains Coal Dominant
Modest Coal to NG Re-dispatch
Strong Wind Power Growth
Nuclear at Risk

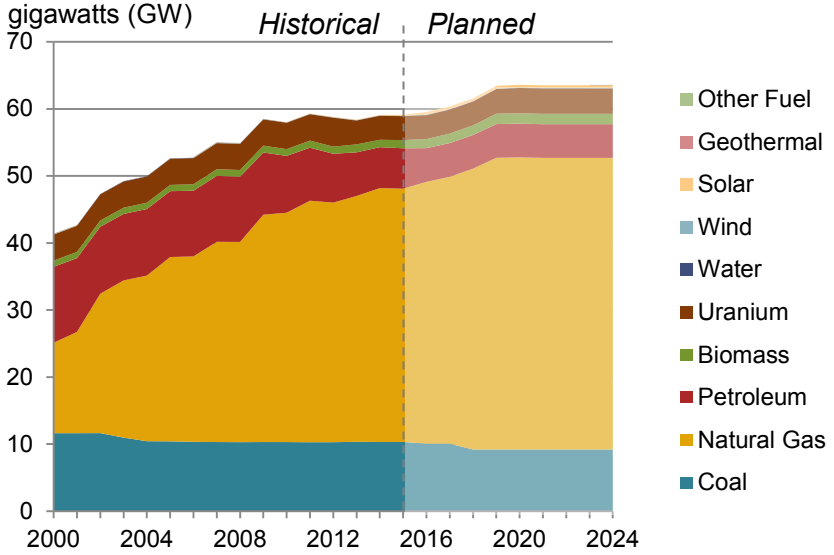
Source: SNL Financial.

Florida

FRCC Annual Generation by Fuel
terawatthours (TWh)

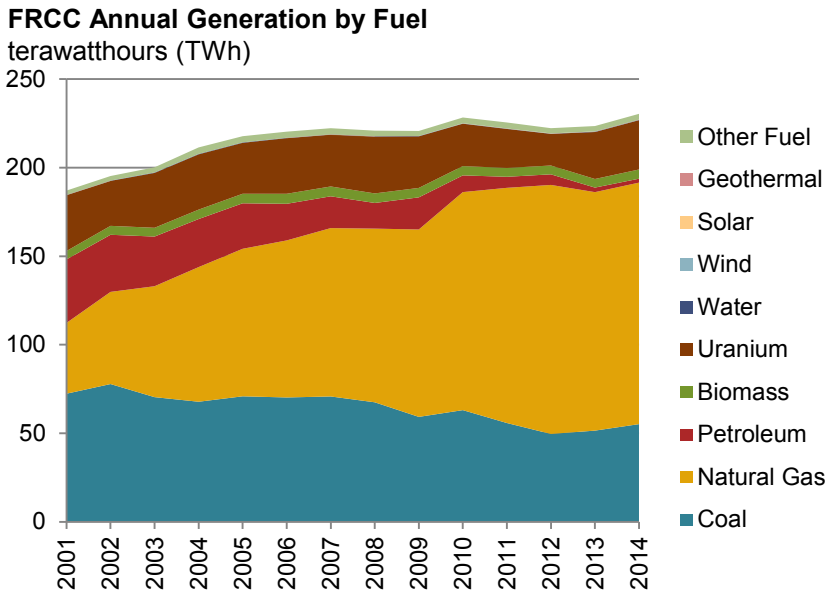


FRCC Capacity by Fuel
gigawatts (GW)

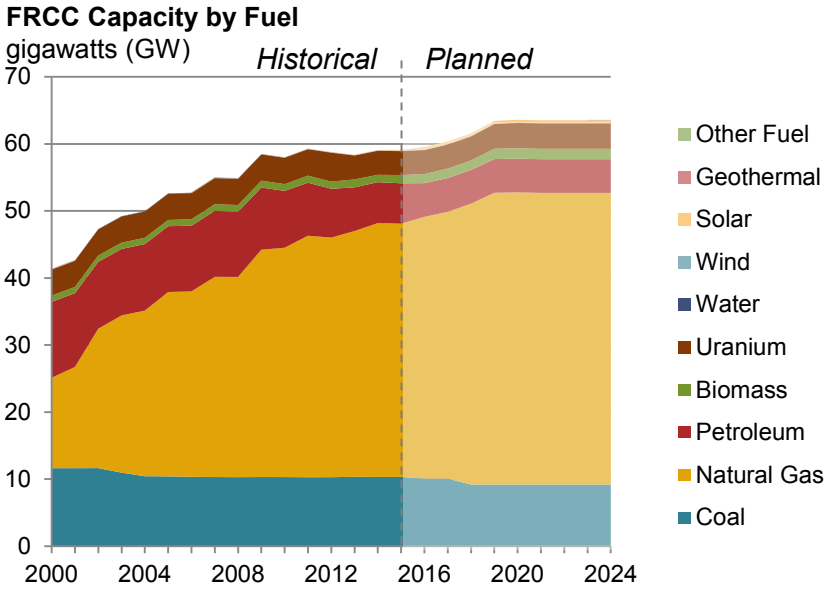


Source: SNL Financial.

Florida



2009-2014
Coal Generation: -7%
NG Generation: +29%
Non-hydro RE: +10%
Total Demand: +4%

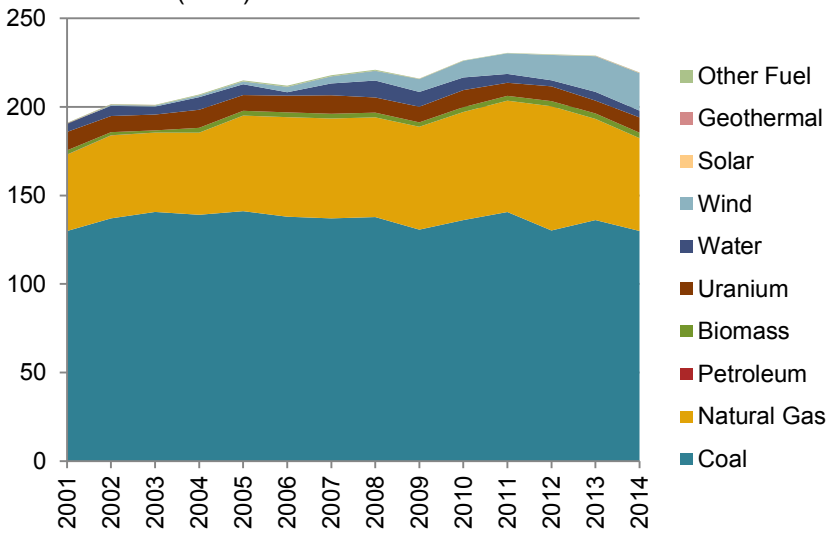


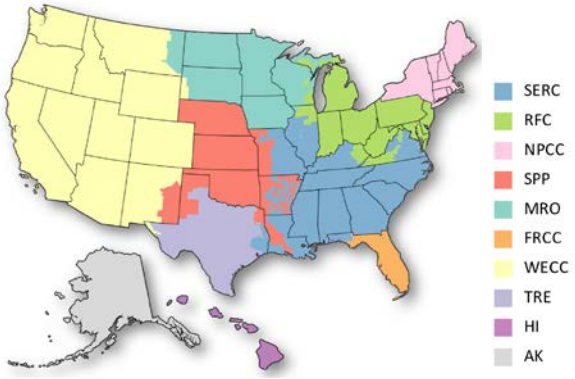
Heavily Reliant on NG, and Increasing
Petroleum Basically Gone
Almost No Renewables

Source: SNL Financial.

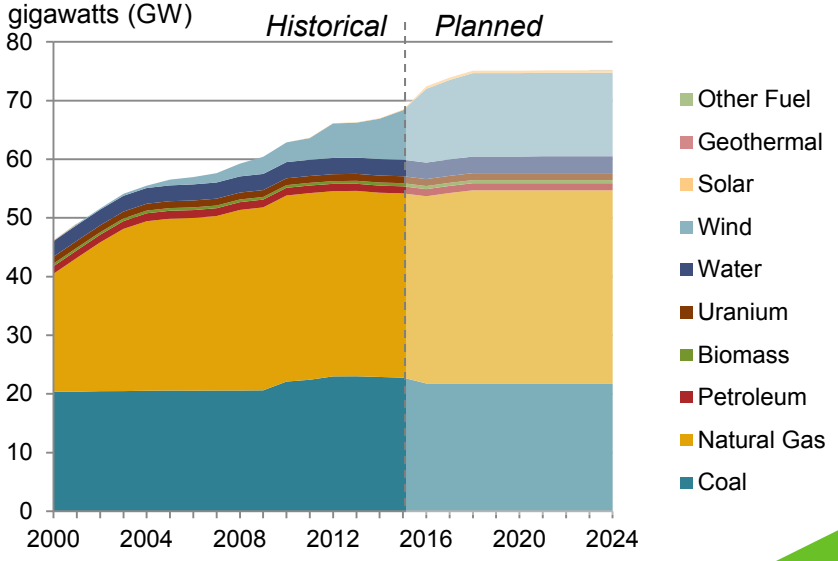
Southwest Region

SPP Annual Generation by Fuel
terawatthours (TWh)



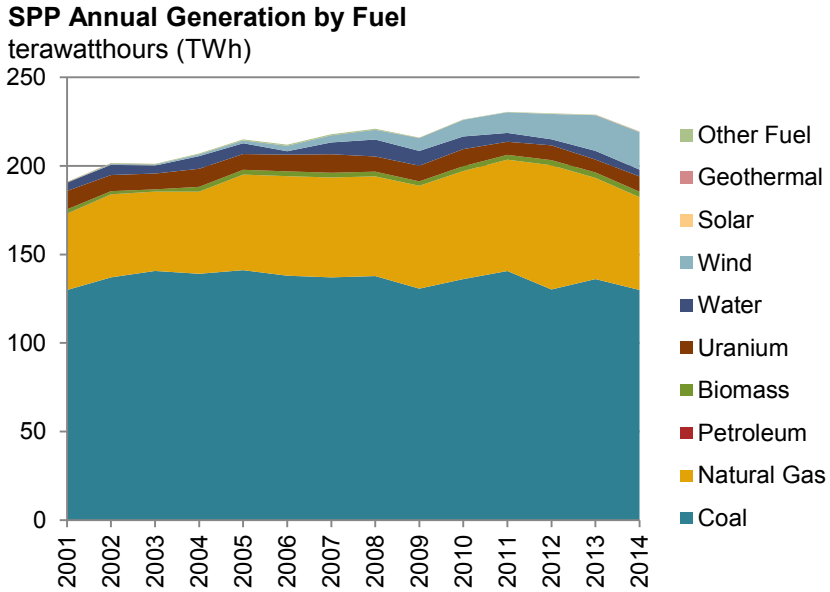


SPP Capacity by Fuel
gigawatts (GW)

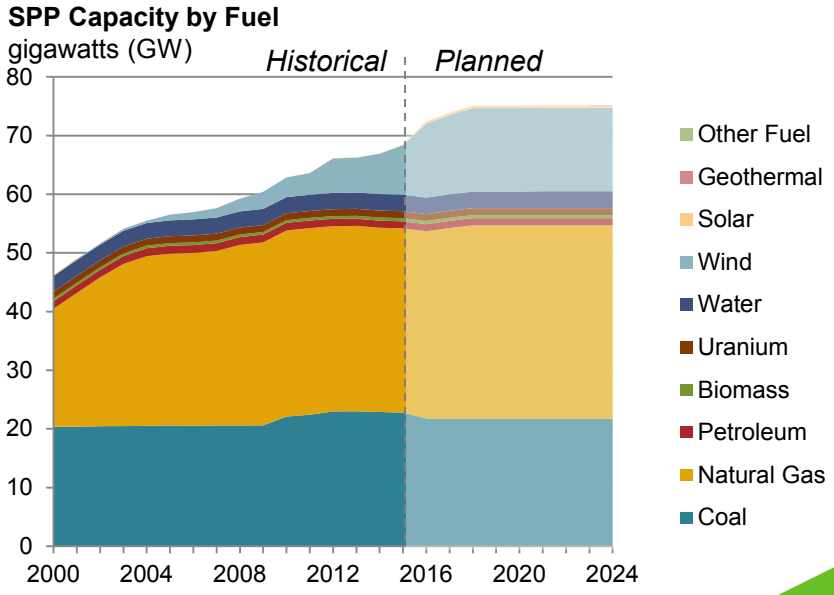


Source: SNL Financial.

Southwest Region



2009-2014
Coal Generation: -1%
NG Generation: -10%
Non-hydro RE: +29%
Total Demand: +2%

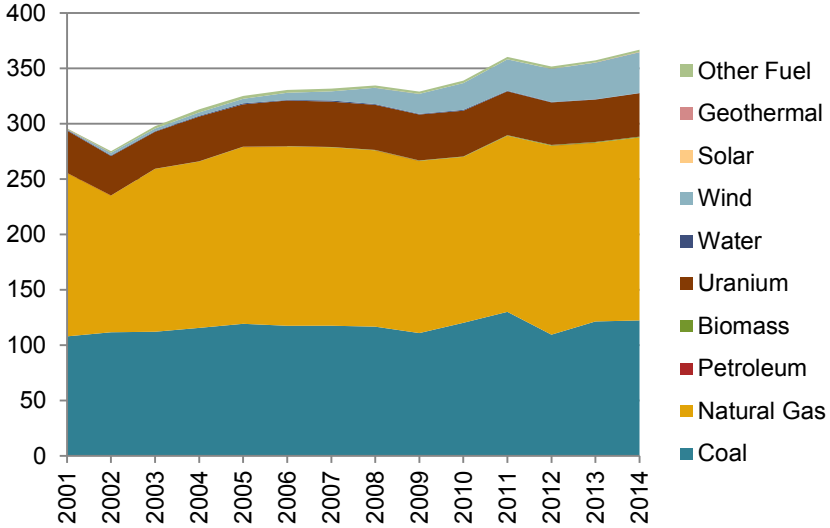


Coal Dominant, But More NG Capacity
Significant Drop in NG Generation
Strong Growth in Wind
Flat Demand

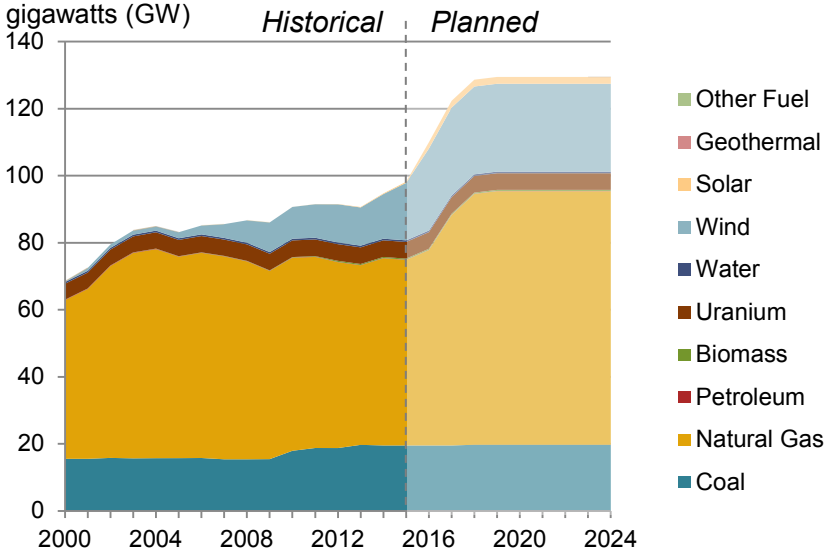
Source: SNL Financial.

Texas

TRE Annual Generation by Fuel
terawatthours (TWh)

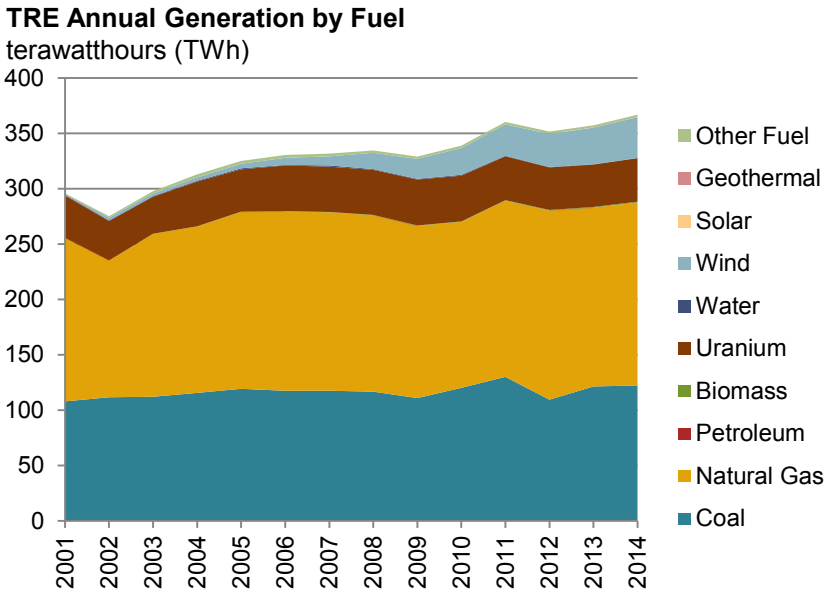


TRE Capacity by Fuel
gigawatts (GW)

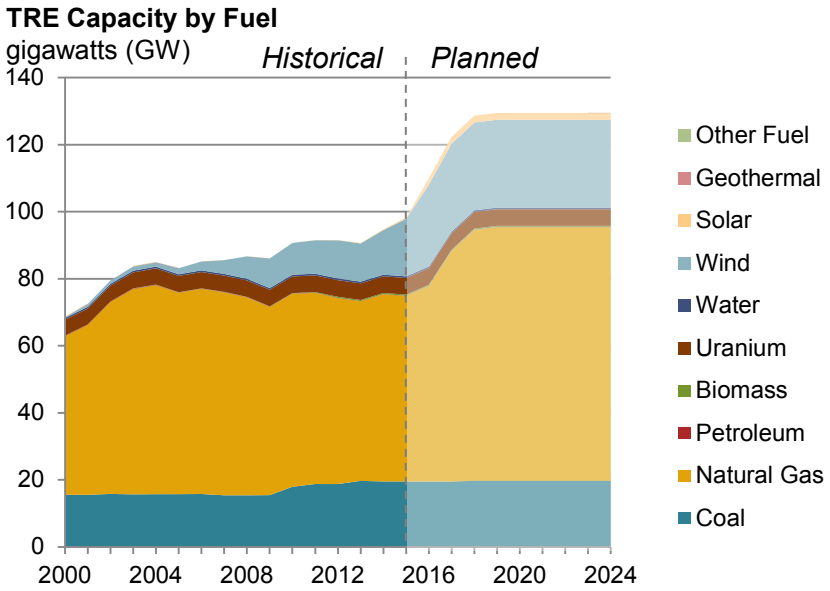


Source: SNL Financial.

Texas



2009-2014
Coal Generation: +10%
NG Generation: +6%
Non-hydro RE: +105%
Total Demand: +12%



Little Re-dispatch from Coal to NG
Strong Growth in Wind
Fastest Growing Demand for Power

Source: SNL Financial.

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Considering the Role of Natural Gas in the Deep Decarbonization of the U.S. Electricity Sector

Wesley Cole, Ross Beppler, Owen Zinaman, and Jeff Logan

April 13, 2016

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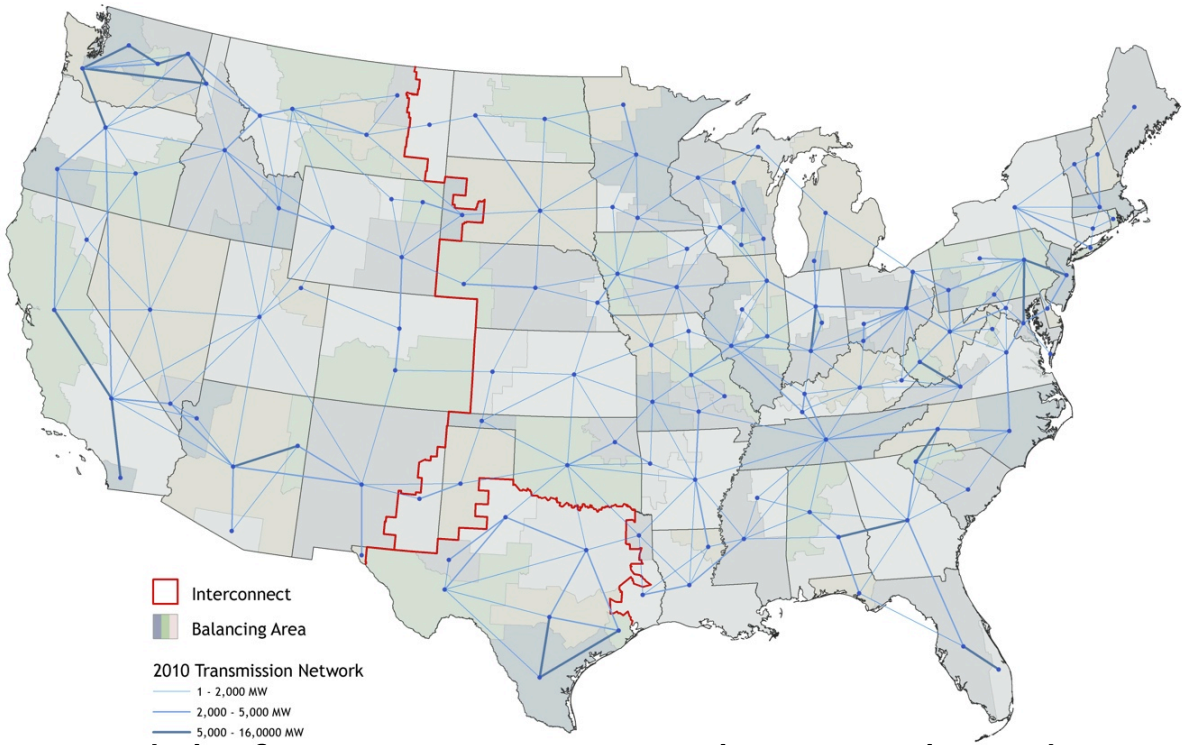
STANFORD UNIVERSITY
University of Colorado Boulder

Introduction

- What is the role of natural gas in transitioning to a decarbonized power system?
- How does that role change according to the attractiveness of other decarbonization pathways?
  - Energy Efficiency
  - Low cost nuclear power
  - Low cost renewable energy (wind and solar)
  - Low cost carbon capture and storage (CCS)

Regional Energy Deployment System (ReEDS) Model

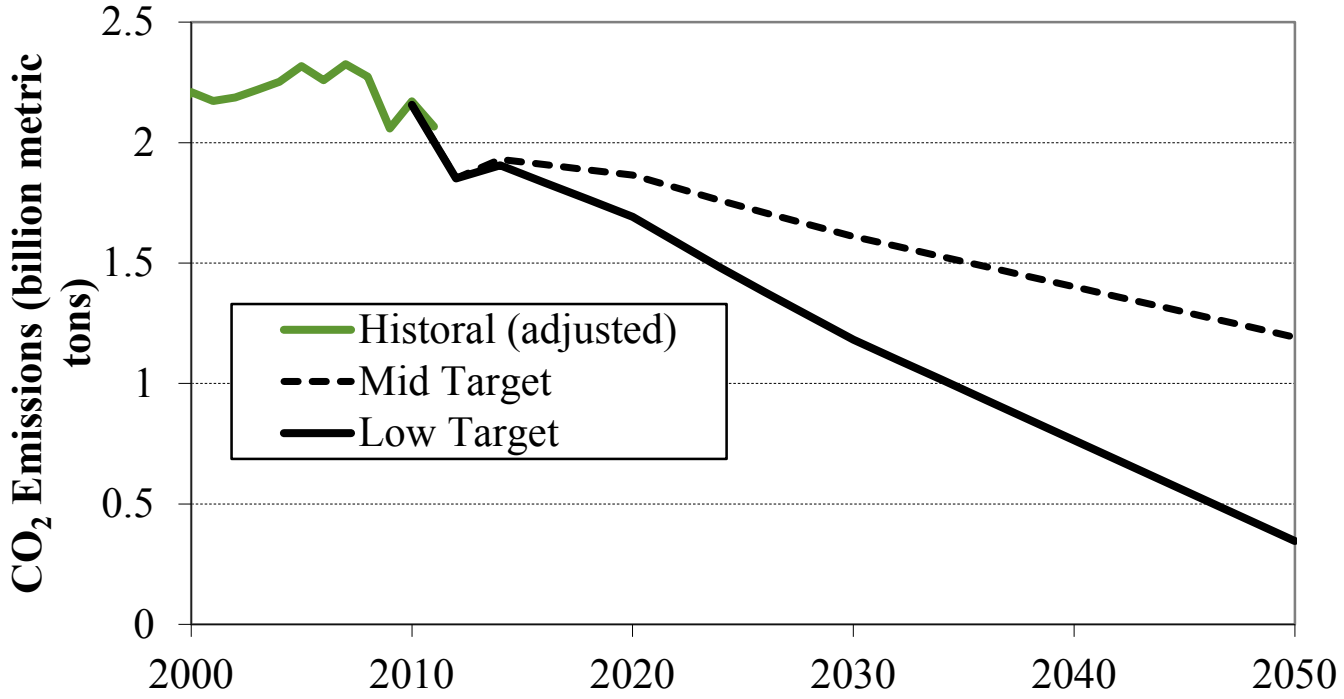


- Optimization model of U.S. Electricity Sector
- 134 Balancing Areas
- 356 Wind/CSP regions
- Explicit consideration of RE integration issues

- Solves combined capacity expansion and dispatch out to 2050 under different assumptions
  - Economic
  - Technology
  - Policy

CO_2 Emission Target Trajectories

- Mid = 41.5% reduction in 2050 from 2005 levels
- Low = 83% reduction in 2050 from 2005 levels



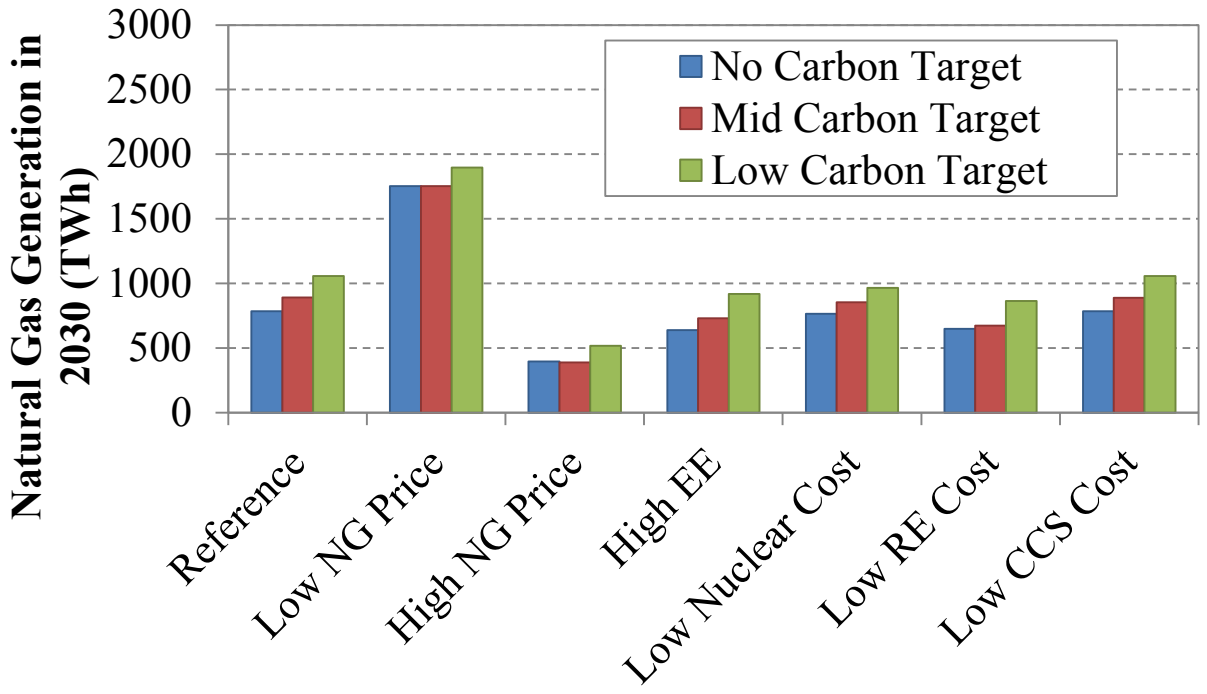
Scenarios Considered

Scenario Name	Scenario Summary
Reference	Mid Renewable Energy Costs from ATB, Conventional Capital and Fuel Costs and Demand Growth from AEO 2015 Reference Scenario
Low NG Price	NG Prices from High Oil & Gas Resource Scenario in AEO 2015
High NG Price	NG Prices from Low Oil & Gas Resource Scenario in AEO 2014
High EE	No changes in end-use demand after 2014
Low Nuclear Cost	30% reduction in nuclear capital costs relative to AEO 2015
Low RE Cost	Low Wind & CSP Cost Trajectories from the ATB; PV reaches $0.75/W in 2040
Low CCS Cost	CCS Costs reach $40/metric ton of CO_2 Captured
Very Low CCS Cost	CCS Costs reach $10/metric ton of CO_2 Captured

*The Clean Power Plan and the 2015 tax credit extensions were not included in these scenarios

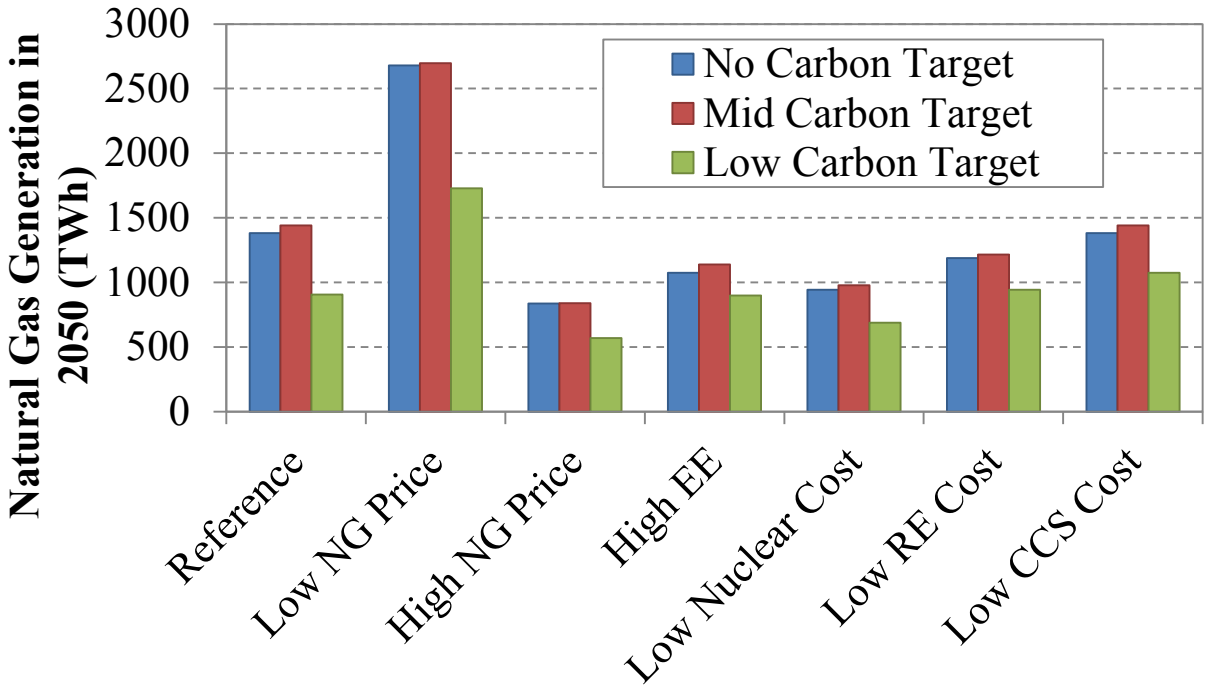
Summary of 2030 Results

- Natural gas (NG) generation increases with the mid and low carbon targets
- NG generation appears to be more sensitive to NG prices rather than technology changes



Summary of 2050 Results

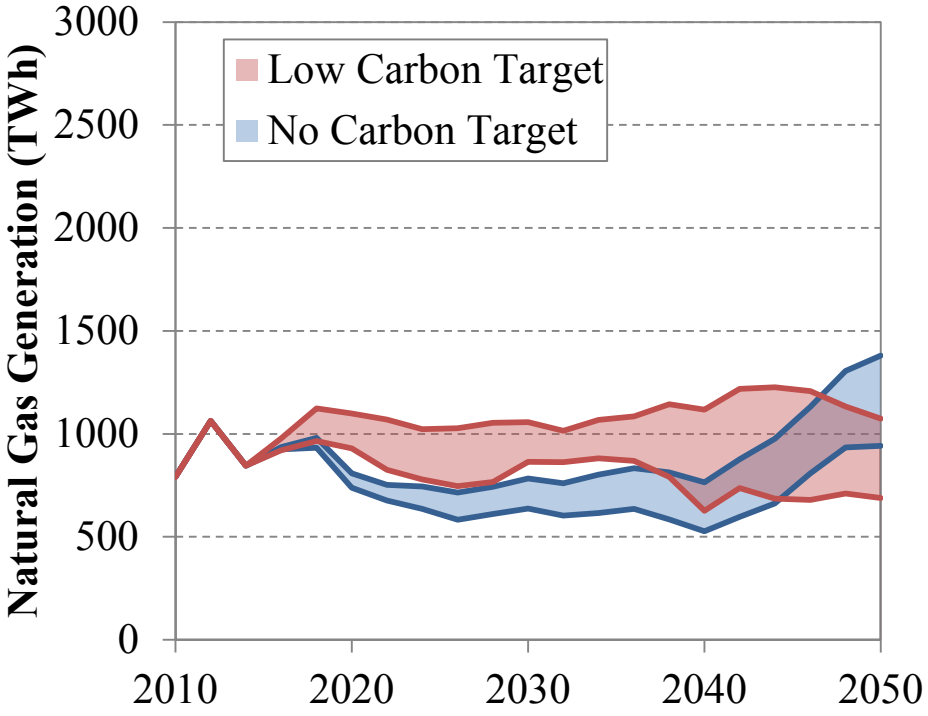
- NG generation increases with a mid carbon target, but decreases with a low carbon target
- NG generation still most sensitive to NG prices than technology changes

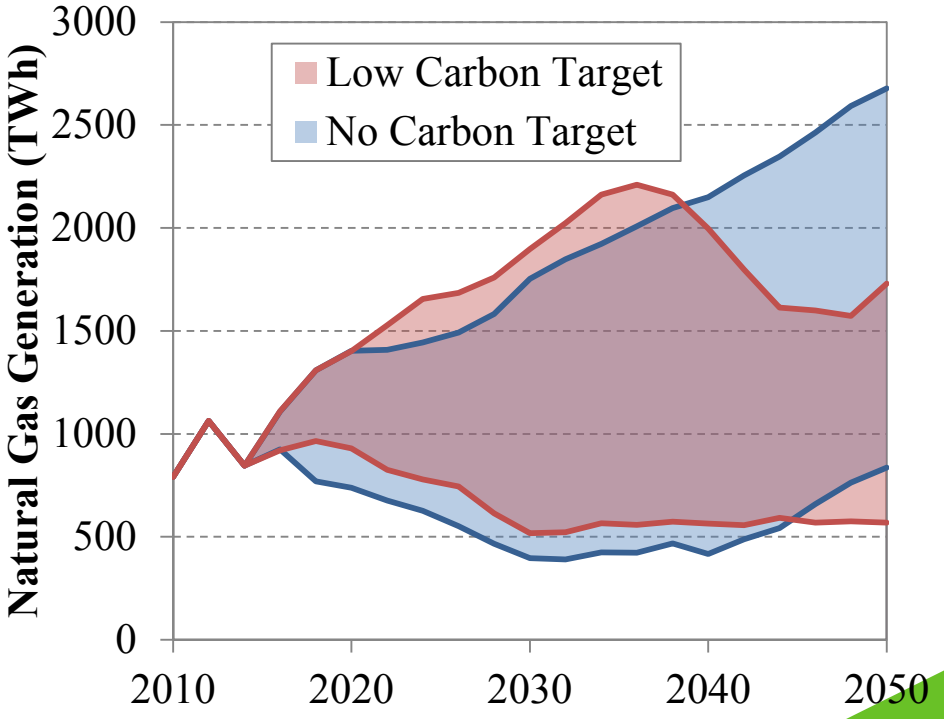


NG Usage is Most Sensitive to NG Price

Left: Range of NG generation under the four technology scenarios

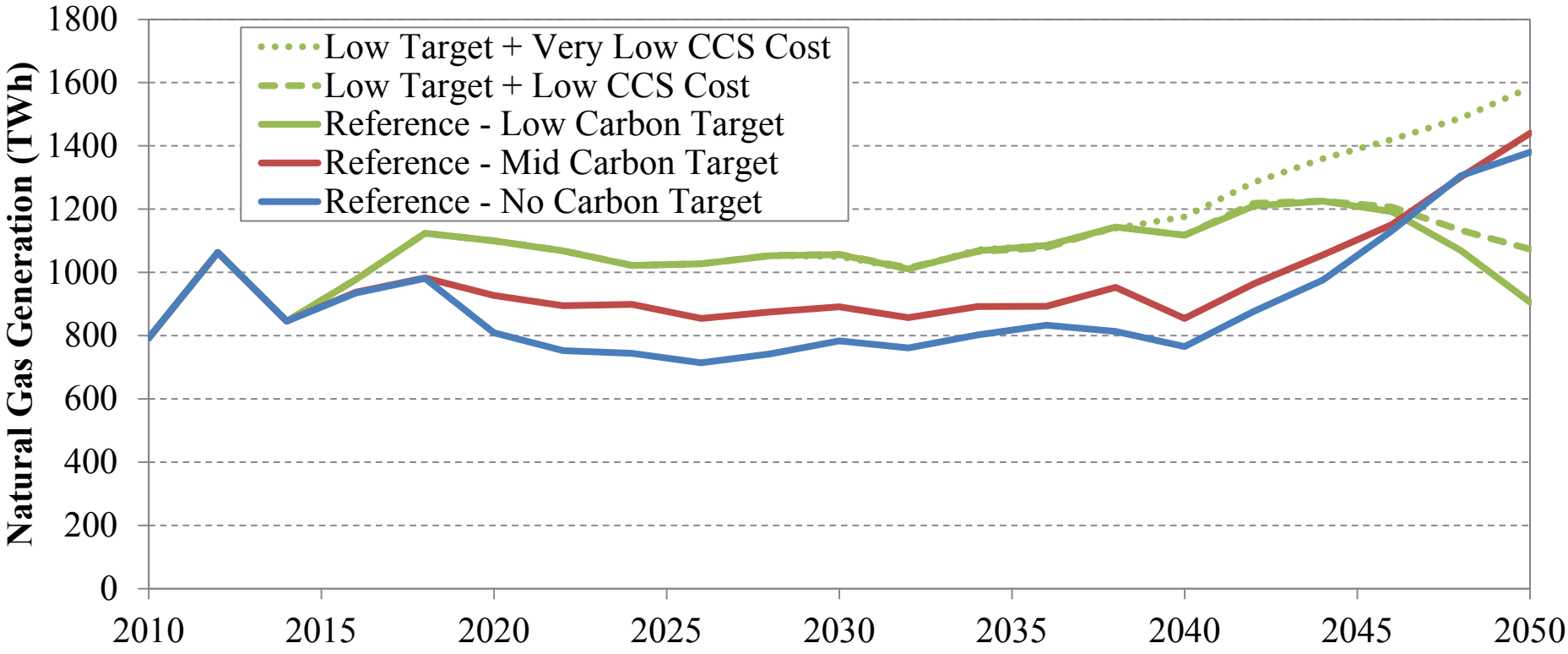
Right: Range of NG generation under the two NG price scenarios





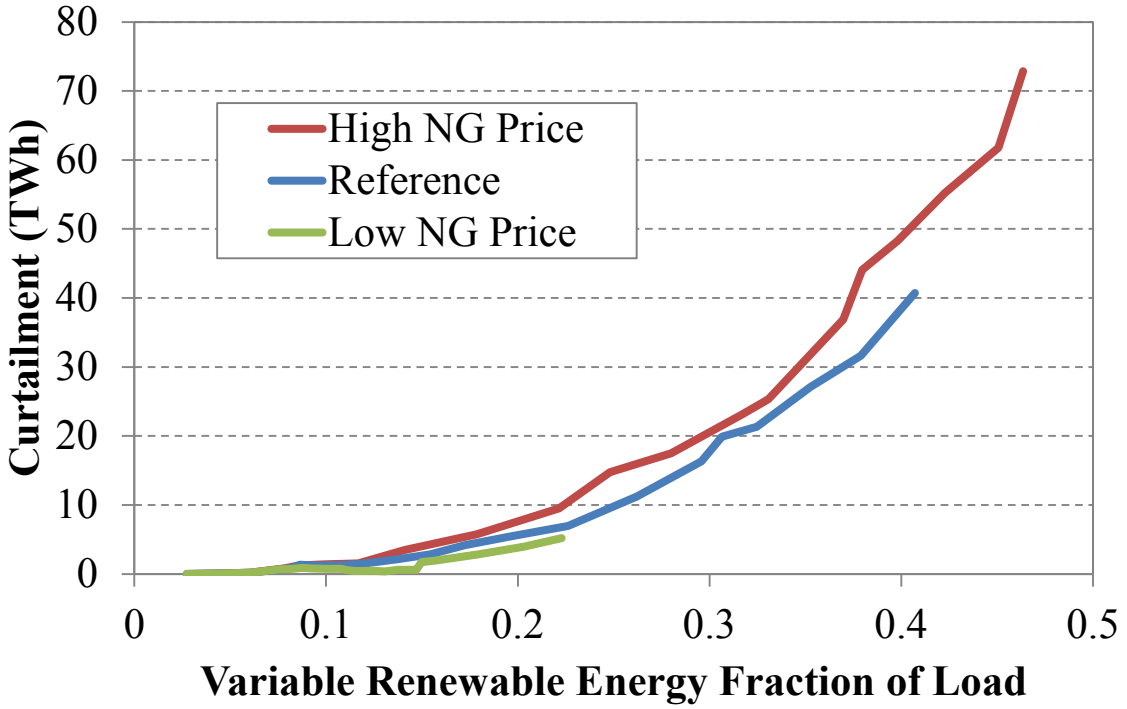
CCS Can Change the Outlook for NG

- Under a low carbon target, NG usage increases over time with competitive CCS



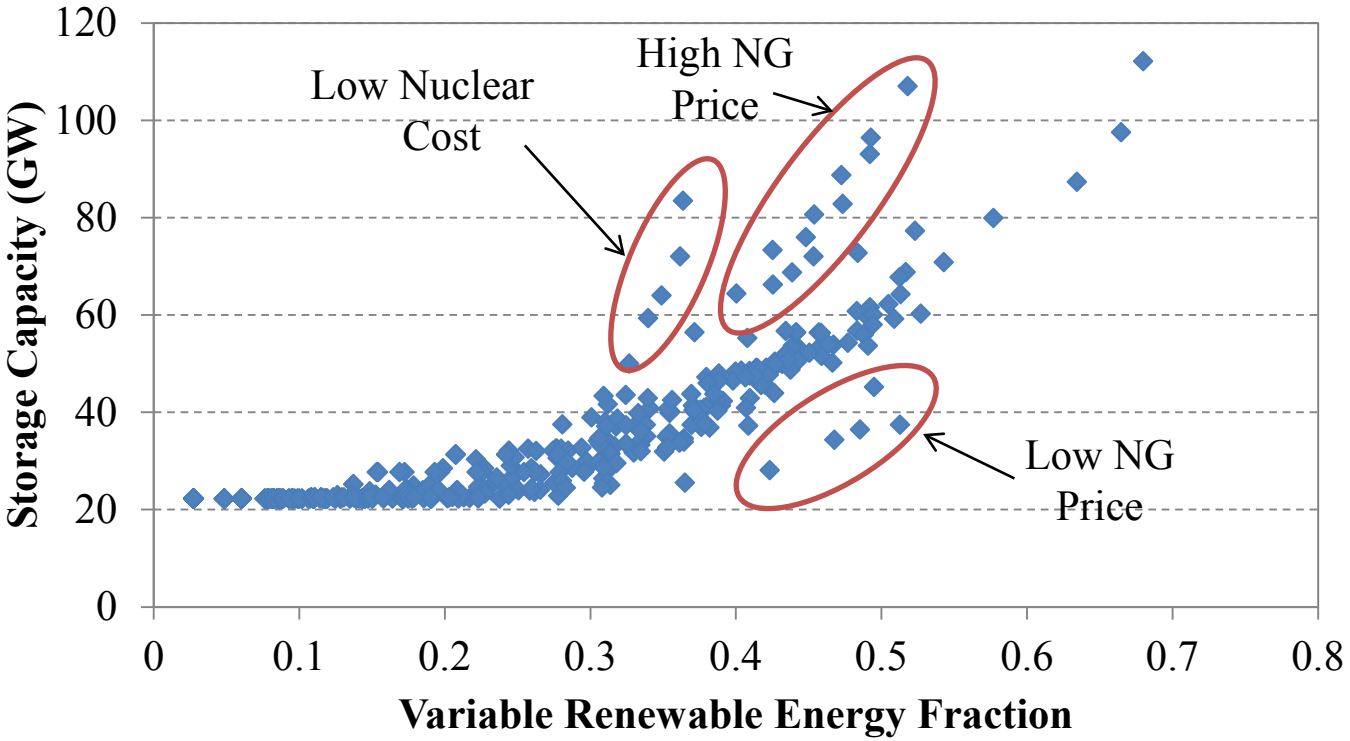
More NG Generation Increases Flexibility

- For the same penetration of variable renewable energy, systems with more NG have lower curtailment



Flexible System Reduces Storage Needs

- Systems with more NG generation require less storage



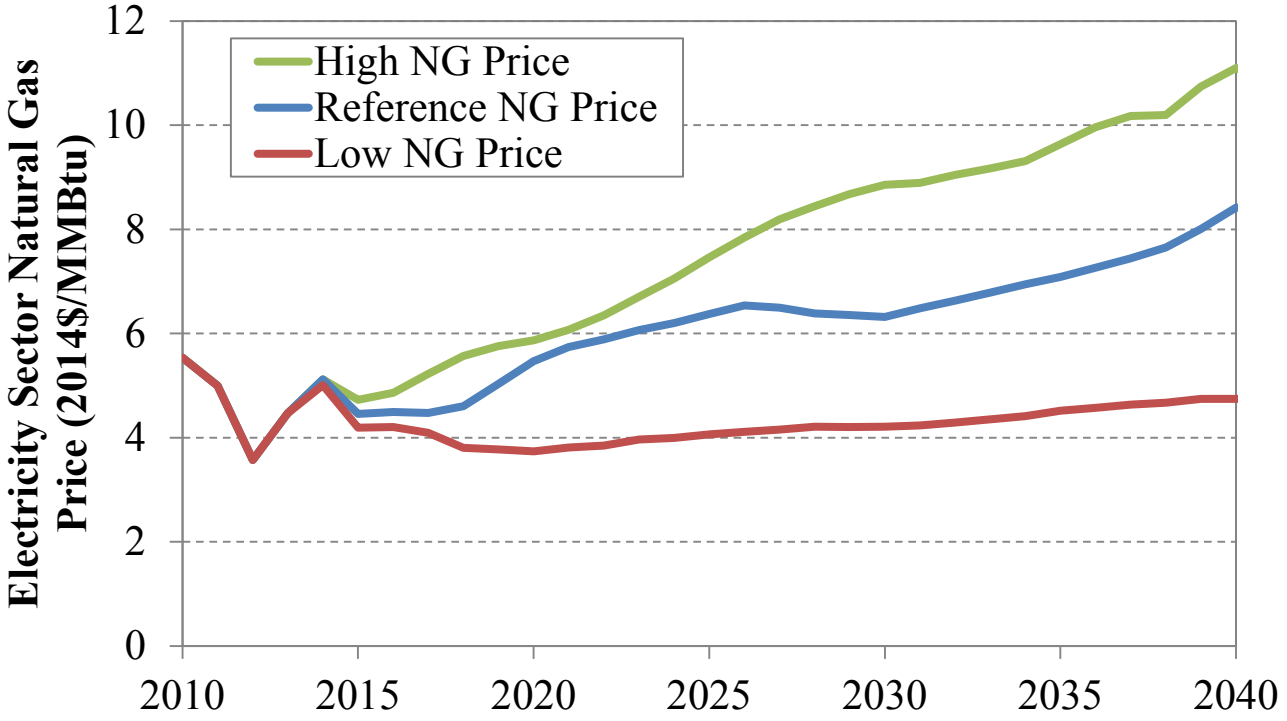
Summary

- Natural gas still provides a substantial amount of generation under a range of decarbonization scenarios
- Natural gas generation shows strong sensitivity to natural gas prices
- Natural gas with low cost CCS can lead to increased natural gas demand over time
- Natural gas can provide additional flexibility the reduces the need to employ other more expensive flexibility options

Additional Slides

Natural Gas Prices

- Natural gas prices are based on Annual Energy Outlook 2014 (high) and 2015 (low and reference)



JISEA Joint Institute for Strategic Energy Analysis

Natural Gas and Renewable Energy:

Lessons Learned from Energy System Stakeholders & Quantifying NG-RE Investments

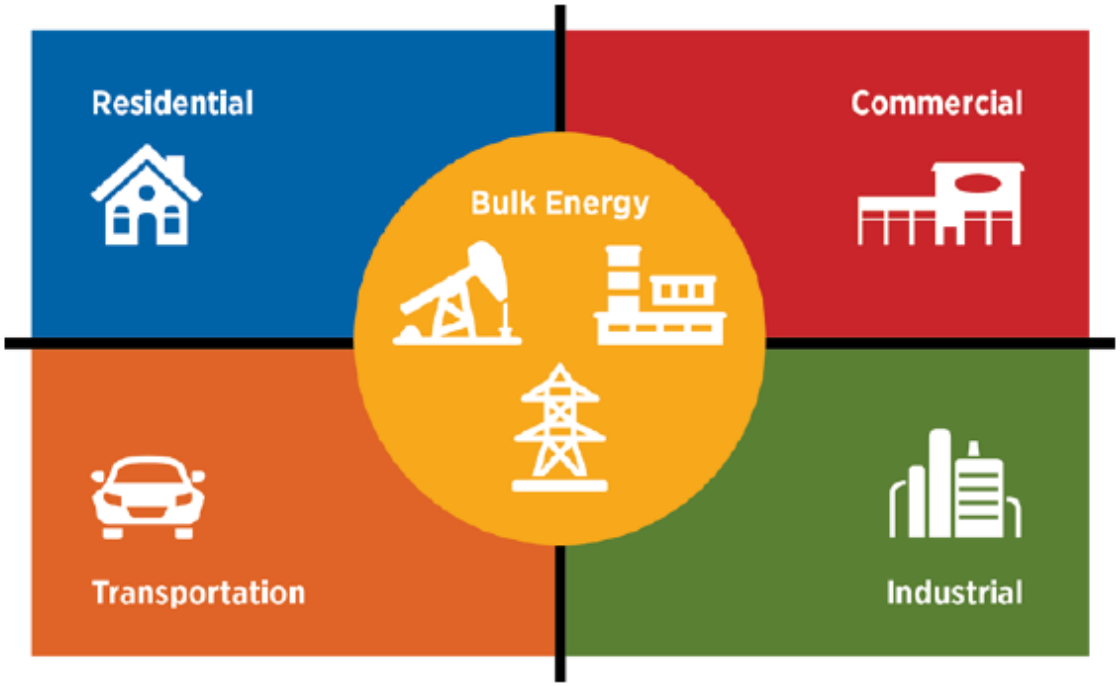
Jacquelyn Pless

April 13, 2016

NREL NATIONAL RENEWABLE ENERGY LABORATORY · COLORADOSCHOOLOFMINES · Colorado State University · Massachusetts Institute of Technology · STANFORD UNIVERSITY · University of Colorado Boulder

Overview

- Natural gas (NG) and renewable electricity (RE) as complements
- Lessons-learned from stakeholder workshops
- Quantifying the value of investing in NG and RE together at the project and system-wide levels



Source: Cochran et al., 2014 (JISEA report)

Synergies of Natural Gas and Renewable Energy: 360 Degrees of Opportunity Workshop Series

Stakeholder participants

- Public utility commissions
- Independent system operators
- Utilities and other generators
- Investors
- Policymakers
- Renewable energy developers
- NG developers
- Original equipment manufacturers
- National laboratories
- Consulting agencies
- Universities and research institutions

Lessons-learned

- Opportunities for NG-RE synergies
  - Large domestic resource base for both NG and RE
  - Complementary risk profiles
  - Energy investments are shifting
  - Financing options are expanding

- Barriers to synergies
  - Economic, technical, and political uncertainties
  - Significant infrastructure investment needs
  - NG-electric market coordination

Lessons-learned (cont.)

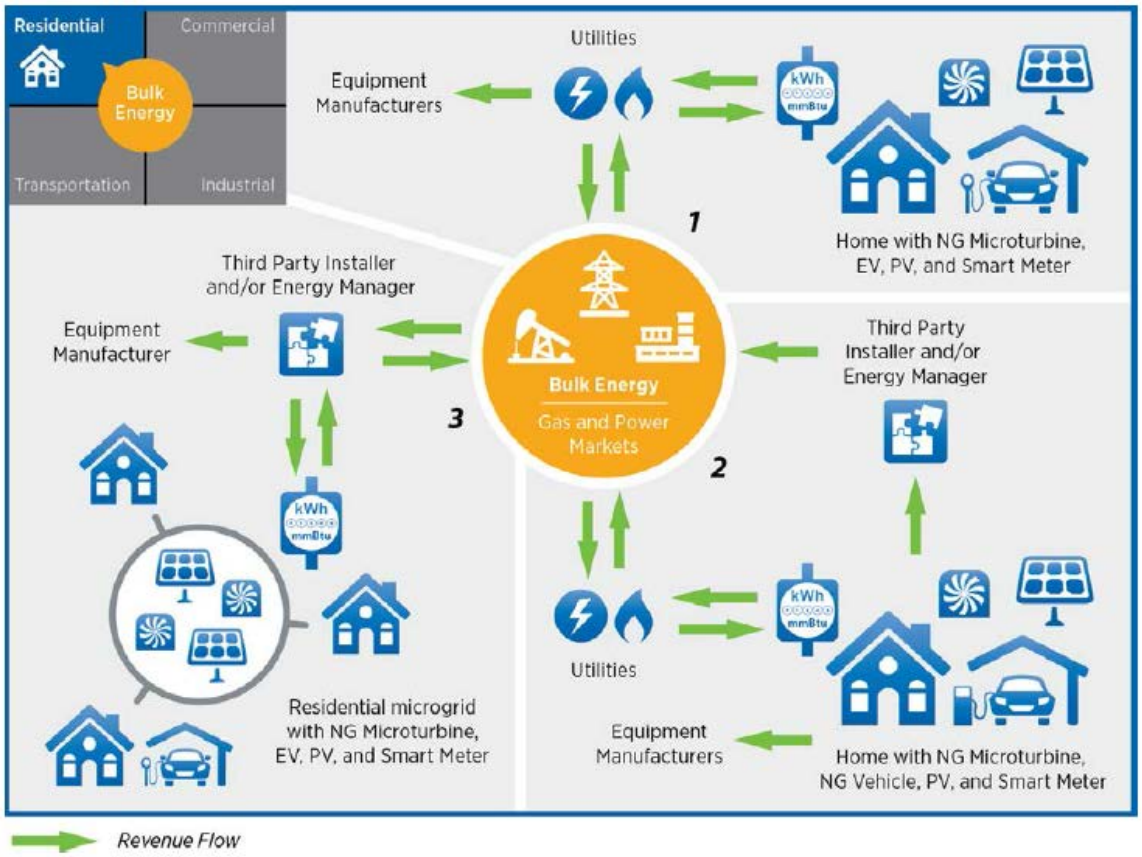
- Electric and gas coordination
  - NG-RE integration and to avoid stranded capital
  - Regional differences in market structures and fuel mixes necessitate a variety of solutions
    - Flexible scheduling and nomination cycles, flexible inter-sector contracting arrangements, managing schedule changes intra-hour, etc.

- Importance of flexibility and diversification
  - Enhances reliability and resiliency (growing need)
  - Valuing flexibility with proper price signals
  - Going beyond LCOE (portfolio management strategies)

Lessons-learned (cont.)

- Energy services provider of the future
  - Creating value for the customer by focusing on reliability and affordability
  - The consumer can create value
    - Customers can offer services of value
    - DR, storage, etc. can add flexibility
- Regulation and wider policy objectives
  - Need market-enabling regulation and policy for NG-RE synergistic investments to be favorable
  - Clean Power Plan, COP21, etc.

Revenue stream opportunities in the residential sector



Examples of revenue opportunities from synergies in the residential sector

1) Utility-managed and financed distributed generation and demand response programs; 2) Privately owned/leased, third-party managed residential energy system; and 3) Neighborhood microgrid managed and operated by third-party energy management company for participation in power markets.

Source: Cochran et al., 2014 (JISEA report)

Distributed Solutions Case Study Overview

Project-level valuation of case studies from the system owner's perspective

- Detailed hourly analysis over project life based upon simulated solar output and stochastic natural gas prices
- Focus on stand-alone systems composed of natural gas microturbines and solar photovoltaic (PV) systems
- Two applications: single residential home and a critical services building (hospital)
- Two locations: New York and Texas
- Methods: discounted cash flow and real options analysis
- Assumptions: system design, costs, performance, and finance structure

Example of Valuation Results

Case-specific assumptions:

- Based in Suffolk County, NY
- Standard v. time-of-use electricity rates
- Baseline NG price volatility
- Net metering v. no net metering

Single Residential Home – Suffolk, NY

System Design	BAU	NG-Only	Solar+Gas	BAU	NG-Only	RE-Only (electricity)	Solar+Gas
Electricity Rates	Standard	Standard	Standard	TOU	TOU	TOU	TOU
Net Metering	No	No	No	Yes	Yes	Yes	Yes
Initial Investment	$0	$34,320	$22,080	$0	$34,320	$14,800	$17,920
NPV	($67,828)	($8,645)	**$2,694**	($66,491)	($9,981)	($38,181)	**$5,061**
NPV (with incentives)			**$8,526**			($34,369)	**$9,750**
Payback (years, w/o incentives)		21.93	14.46		23.1	>24	12.60
Payback (years, w/incentives)			6.45			>24	4.27
Option Value (no incentives)		**$5,068**	**$24,426**		**$1,077**	($33,682)	**$47,972**

Example of Valuation Results

Case-specific assumptions:

- Based in Suffolk County, NY
- Standard v. time-of-use electricity rates
- Baseline NG price volatility
- Net metering v. no net metering

Critical Services Building (Hospital) – Suffolk, NY

System Design	BAU	NG-Only	Solar+Gas	BAU	NG-Only	RE-Only (electricity)	Solar+Gas
Electricity Rates	Standard	Standard	Standard	TOU	TOU	TOU	TOU
Net Metering	No	No	No	Yes	Yes	Yes	Yes
Initial Investment	$0	$2.21M	$5.85M	$0	$2.21M	$3.6M	$5.85M
NPV	($17.9M)	**$8.10M**	**$6.99M**	($18.0M)	**$8.23M**	($13.9M)	**$7.12M**
NPV (with incentives)			**$8.46M**			($12.9M)	**$8.59M**
Payback (years, no incentives)		2.51	4.98		2.24	>30	4.54
Payback (years, solar incentives)			3.25			>30	2.96
Option Value (no incentives)		**$104M**	**$119M**		**$105M**	($15.6M)	**$121M**

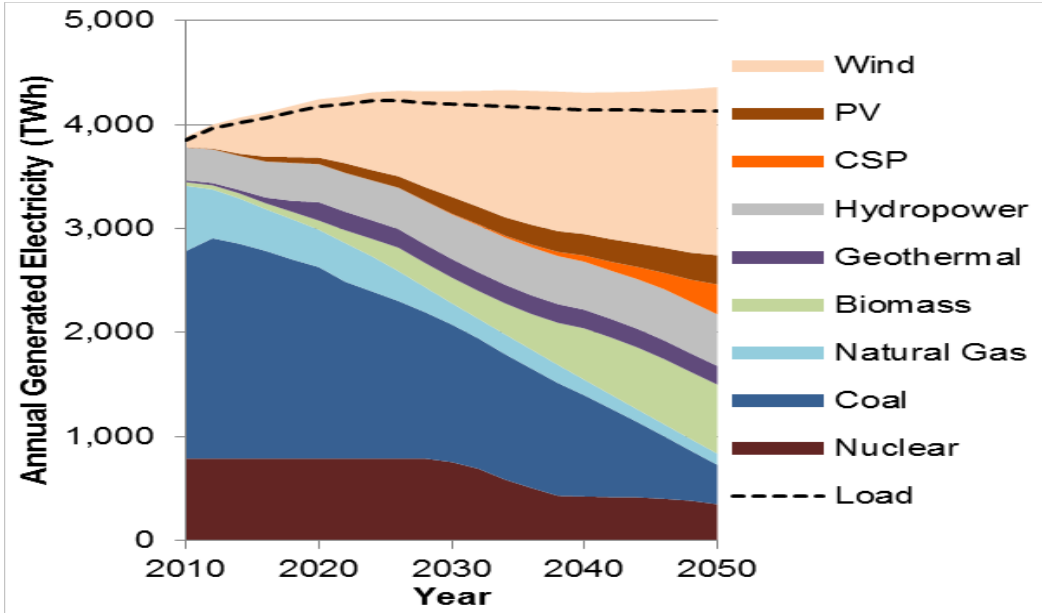
DG Valuation Key Observations

- Hybrid systems are generally favorable relative to stand-alone alternatives or BAU
  - *Some sensitivities*: scale, gas demand, gas price volatility, efficiency of microturbines, availability of incentives for RE
- All DG cases studied are favored over BAU
- Importance of enabling policy environment

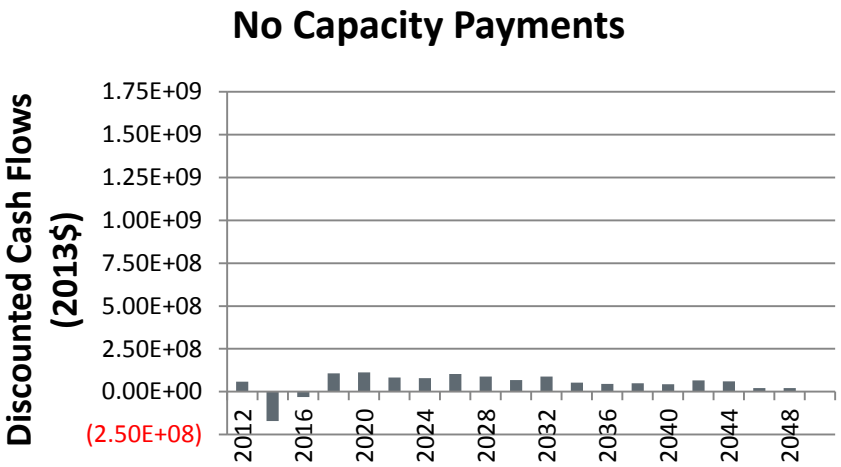
Pathways to a low carbon system

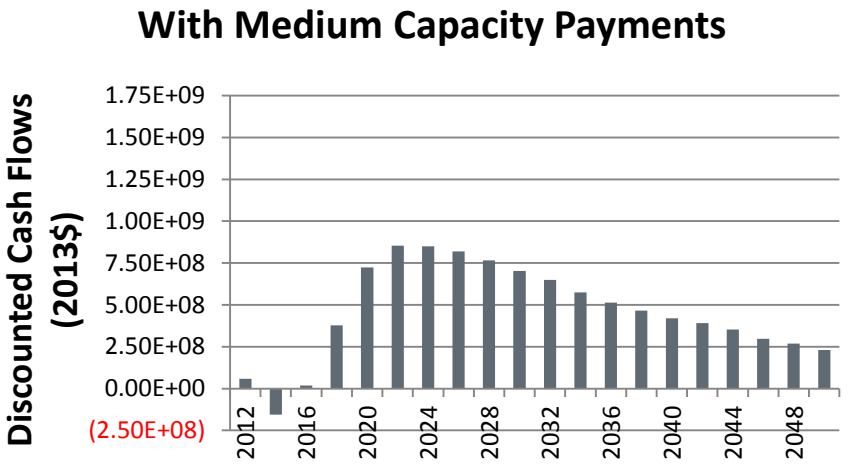
- Output from Renewable Electricity Futures Study
  - 80% RE by 2050
  - Bulk power system generation
  - Wholesale market price/structure sensitivity (Not a detailed dispatch analysis)
- Given long term trajectory toward higher RE, are natural gas units profitable?

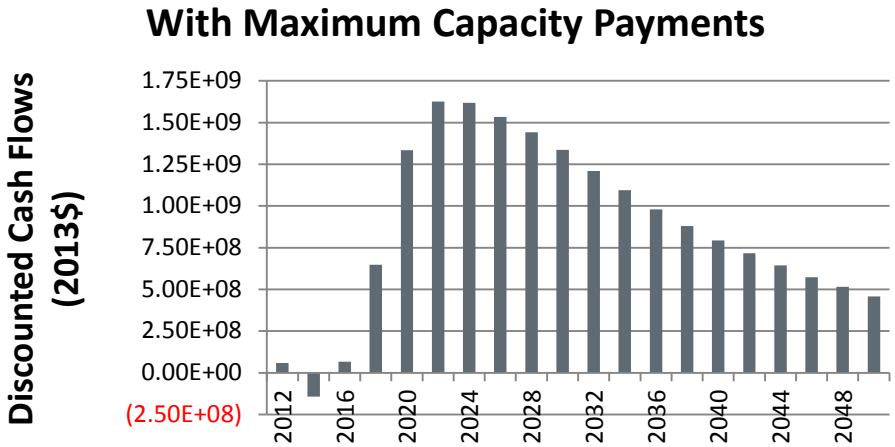
Generation by Energy Resource: 80% by 2050 (ITI Scenario)



Wholesale – Natural gas CC with capacity payments







Thank you!

Questions?

These publications are available online at
www.jisea.org/publications.cfm

- *A Review of Sector and Regional Trends in U.S. Electricity Markets: Focus on Natural Gas:* http://www.nrel.gov/docs/fy16osti/64652.pdf
- *Considering the Role of Natural Gas in the Deep Decarbonization of the U.S. Electricity Sector:* http://www.nrel.gov/docs/fy16osti/64654.pdf
- *Pathways to Decarbonization: Natural Gas and Renewable Energy, Lessons Learned from Energy System Stakeholders*: http://www.nrel.gov/docs/fy15osti/63904.pdf

Next Webinar

Wednesday, April 20 at 10 a.m. MDT

Environmental, Economic, and Technological Effects of Methane Emissions and Abatement

With Garvin Heath, Ethan Warner, and David Keyser of NREL

Register at www.jisea.org/news.cfm