EPRI Social Cost of Carbon Webcast Series

Today: Social Cost of Carbon Pricing of Power Sector CO_2

August 16, 2017

© 2017 Electric Power Research Institute, Inc. All rights reserved.

EPRI Webcast Series

- July 25, 2017 (1:30-3 pm EDT)
  - *Understanding the Social Cost of Carbon: A Model Diagnostic and Inter-Comparison Study*
- August 16, 2017 (2-3 pm EDT)
  - *Social Cost of Carbon Pricing of Power Sector CO_2: Accounting for Leakage and Other Social Implications from Subnational Policies*
- September 5, 2017 (2-3 pm EDT)
  - *Applying the Social Cost of Carbon: Technical Considerations*

Publications and slides available at http://eea.epri.com ("Research" tab). For information: Steven Rose, srose@epri.com.

© 2017 Electric Power Research Institute, Inc. All rights reserved.

Social Cost of Carbon Pricing of Power Sector CO_2

Accounting for Leakage and Other Social Implications from Subnational Policies

John Bistline and Steven Rose

EPRI Energy and Environmental Analysis Group

Webcast

August 16, 2017

© 2017 Electric Power Research Institute, Inc. All rights reserved.

Motivations

- **Social Cost of Carbon (SCC)** is an important metric
  - An estimate of damages to society from CO_2
  - An estimate of the benefits of avoiding CO_2
- SCCs are increasingly being considered and used
  - Federal, state, local, and other decisions-makers
- However, SCC *application* issues can affect estimated climate and net benefits (Rose and Bistline, 2016)
  - Issues beyond SCC *estimation* (see previous webcast)
- One application issue: **net global CO_2 emissions changes** are not considered
  - An SCC is the estimated value of a net incremental change in **GLOBAL** CO_2
  - Regulations do not typically estimate CO_2 changes beyond the regulated segment (i.e., leakage)
  - x% positive leakage = x% lower CO_2 reduction benefits

Examples of Types of SCC Applications

Application type	Examples	Global emissions implications	SCCs used
Federal regulatory	DOT (NHTSA) vehicle efficiency standards, EPA Clean Power Plan, DOE small motor efficiency standard, DOE microwave efficiency standard (1, 2, 3, 4)	Incremental	USG
Federal non-regulatory	CEQ NEPA reviews, BLM coal mine permitting (5, 6)	Incremental	USG
State	Minnesota, Maine (7, 8)	Incremental	USG considered
Local (e.g., city)	Austin, TX (9)	Incremental	Custom
Value of technology	Technology SCC pricing (10)	Incremental	USG and other
Non-U.S. regulatory	Canada, United Kingdom (U.K.) (11, 12)	Incremental	Canada – USG UK – Custom
Federal climate goal evaluation	U.S. proposed legislative GHG cap and trade policy (12)	Non-incremental	USG
Global climate goal evaluation	Tol (2009) (13)	Non-incremental	Custom

Rose and Bistline (2016)

© 2017 Electric Power Research Institute, Inc. All rights reserved.

Motivations (continued)

- Leakage acknowledged in Minnesota Public Utilities Commission CO_2 externalities pricing proceedings
  - Judge recommended investigating how to measure and consider leakage
- This analysis explores the potential for U.S. power sector CO_2 leakage, and other social implications, with subnational policies
  - Increased subnational action (region, state, local) with federal climate policy uncertainty
  - Important to evaluate environmental/economic impacts
  - Limited literature, with limitations in the modeling
- Discussion paper forthcoming (refinement of analysis in Rose and Bistline, 2016) with a peer-reviewed paper in review

Bistline and Rose (forthcoming), Social Cost of Carbon Pricing of Power Sector CO_2: Accounting for Leakage and Other Social Implications from Subnational Policies

EPRI Discussion Paper

Social Cost of Carbon Pricing of Power Sector CO_2: Accounting for Leakage and Other Social Implications from Subnational Policies

John E. Bistline* and Steven K. Rose

Electric Power Research Institute, Palo Alto, CA 94304

Abstract

In environments where climate policy has partial coverage or unequal participation, carbon dioxide (CO_2) emissions or economic activity may shift to locations and sectors where emissions are unregulated. This is referred to as leakage. Leakage can offset or augment emissions reductions associated with a policy, which has important environmental and economic implications. Although leakage has been studied at national levels, analysis of leakage for subnational policies is limited, despite greater market integration and many existing state and regional environmental regulations in the U.S. This study explores leakage potential, net emissions changes, and other social implications in the U.S. energy system with regionally differentiated pricing of power sector CO_2 emissions. We undertake an economic analysis using EPRI's US-REGEN model, where power sector CO_2 emissions are priced in individual U.S. regions with a range of social cost of carbon (SCC) values. SCC estimates are being considered by policy-makers for valuing potential societal damages from CO_2 emissions. In this study, we evaluate the emissions implications within the SCC pricing region, within the power sector outside the SCC region, and outside the power sector (i.e., in the rest of the energy system) and estimate other potential societal effects, such as to electricity prices, power sector investments, and overall consumption. Our results indicate that CO_2 leakage is possible within and outside the electric sector that would affect CO_2 reduction benefits, ranging from negative 70% to over 80% in our scenarios, with primarily positive leakage outcomes. Electricity price changes and broader economic effects are also observed within and across regions. Constraining power imports into the SCC pricing region likely reduces leakage, but could also result in lower overall emissions reductions, as well as larger price increases. Leakage rates, net emissions outcomes, electricity price changes, fuel market effects, and macroeconomic costs vary by region of the country, time, policy stringency, policy design (e.g., leakage mitigation provisions), policy environment in neighboring regions, and price responsiveness of demand.

Keywords: Climate policy; social cost of carbon; emissions leakage; state-based regulations; regulatory impact analysis; energy-economic modeling

Rose and Bistline (2016), Applying the Social Cost of Carbon: Technical Considerations

EPRI Report #3002004659

© 2017 Electric Power Research Institute, Inc. All rights reserved.

Modeling of SCC Pricing of Power Sector CO_2

Primary questions of interest:

1. Is there CO_2 emissions leakage?
2. What are the net CO_2 implications?
3. Are there other social implications?

Exploration into potential for CO_2 leakage and economic implications

Finding insights with broad relevance (e.g., CPP)

Outputs of interest:

- CO_2 emissions changes – power sector, economy-wide
- Electricity price changes
- Power system responses – generation, capacity, trade
- Energy use responses – electric vs. non-electric
- Macro indicators (e.g., GDP, consumption, surplus)

© 2017 Electric Power Research Institute, Inc. All rights reserved.

Primary Insights from the SCC Pricing Analysis

CO_2 leakage potential

- CO_2 leakage is possible within and outside the electric sector that would affect CO_2 reduction benefits
- Benefits calculations that ignore leakage would be incorrect – too high if there is positive leakage, and too low if there is negative leakage

Price effects and policy costs

- Electricity price changes are possible within and across regions that would affect consumers
- Electric sector and macroeconomic costs are also possible within a region and nationally

Potential leakage management: constraining power imports into the SCC pricing region (or pricing CO_2 imports) likely reduces leakage, but also results in larger price increases and lower net CO_2 reductions

Effects vary: by region, time, policy stringency, policy design (e.g., leakage mitigation provisions), policy environment in neighboring regions, and price responsiveness of demand

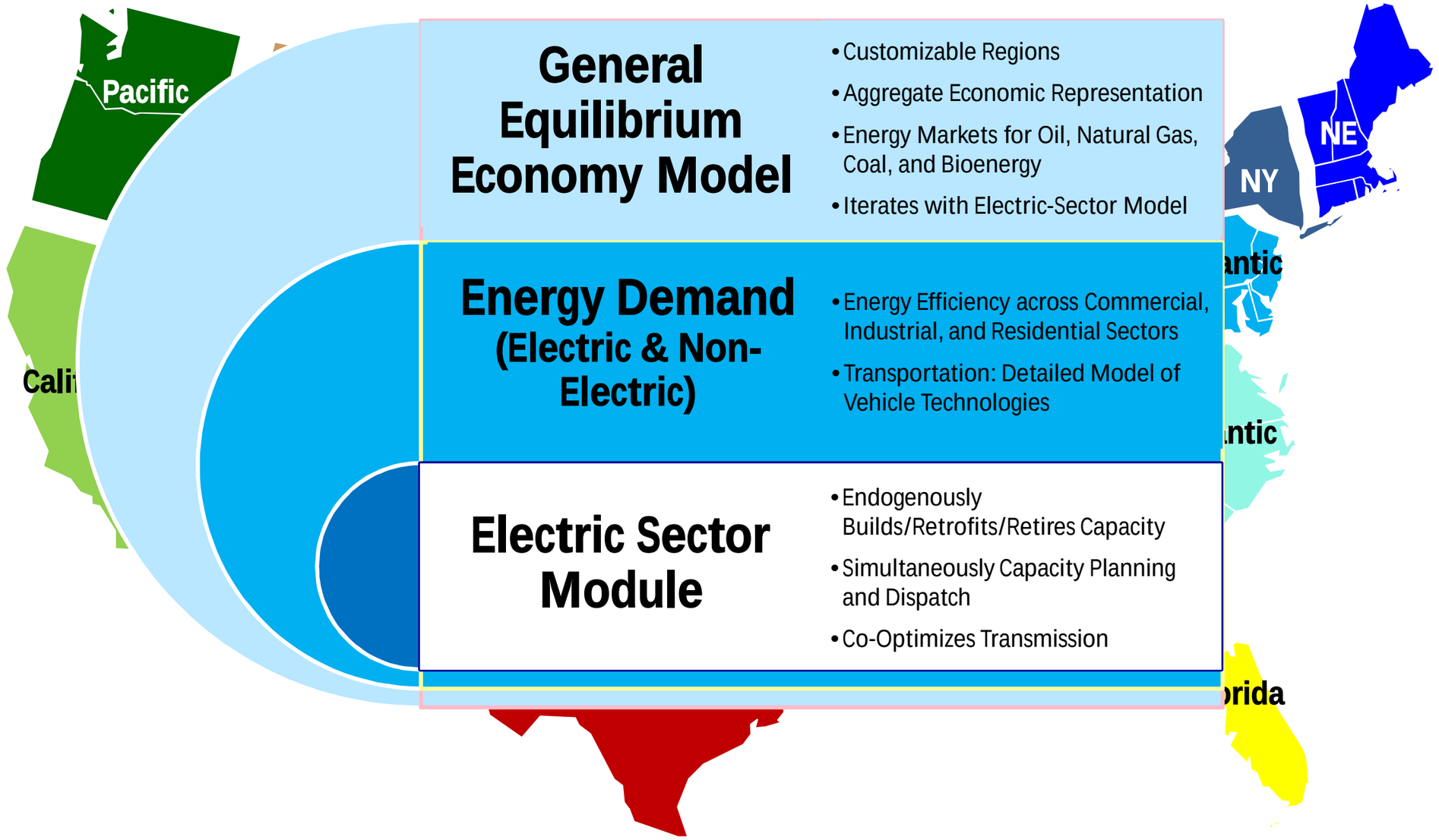
Overall insights: CO_2 leakage is possible when there are differences in regional power sector CO_2 policy stringency; additional environmental and economic metrics are important to consider

© 2017 Electric Power Research Institute, Inc. All rights reserved.

Modeling Framework and Scenarios

© 2017 Electric Power Research Institute, Inc. All rights reserved.

U.S. Regional Economy, GHG, and Energy (US-REGEN)



© 2017 Electric Power Research Institute, Inc. All rights reserved.

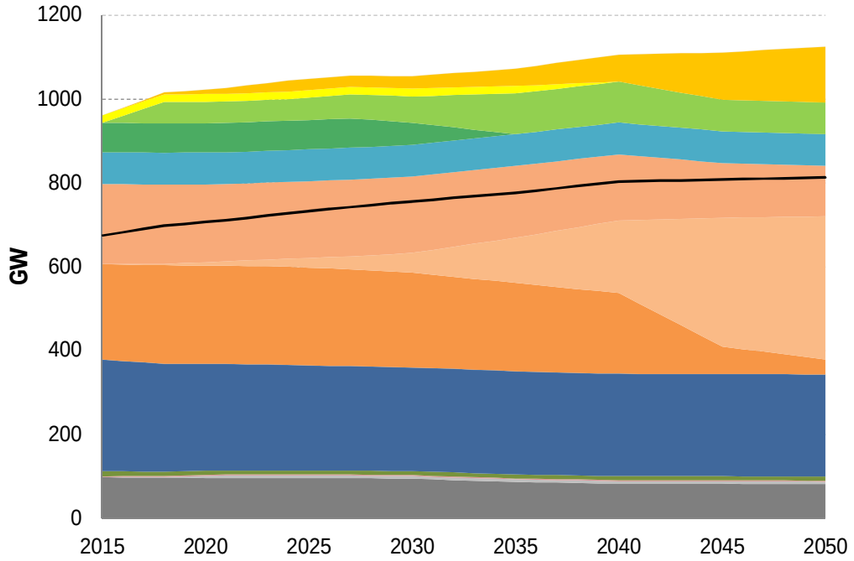
US-REGEN: EPRI's In-House Electric Sector and Economy Model

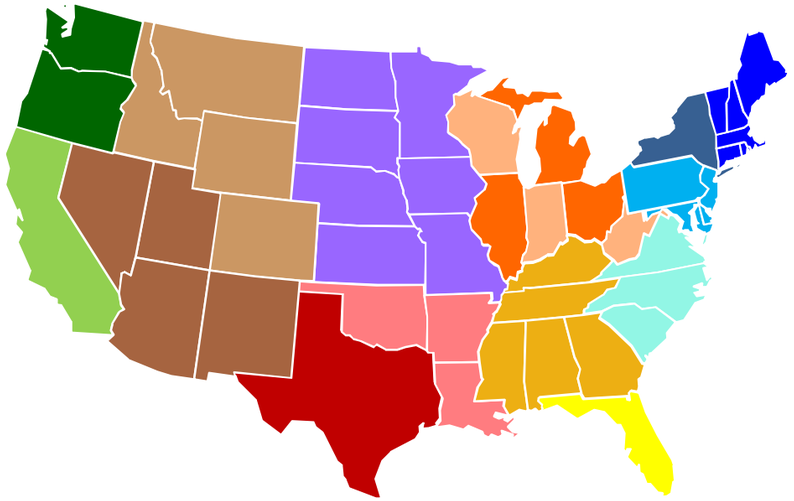
U.S. Regional Economy, GHG, and Energy

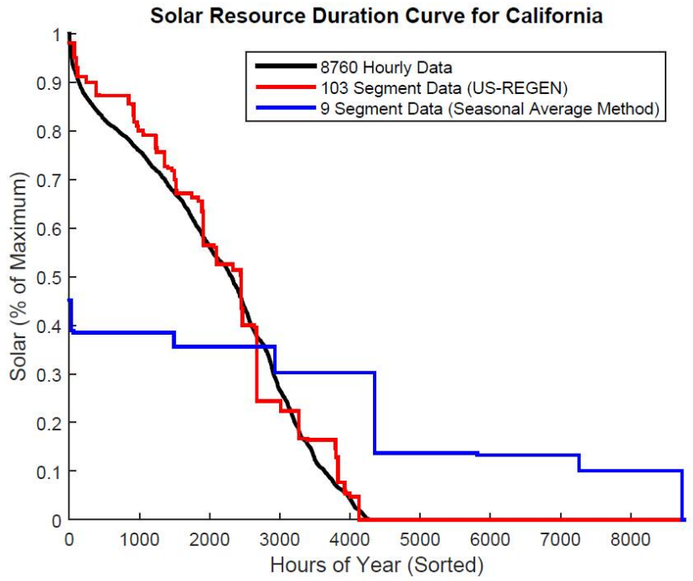
Capacity Expansion Economic Model, Long Horizon to 2050

Customizable State/Regional Resolution for Policy and Regulatory Analysis

Innovative Algorithm to Capture Wind, Solar, and Load Correlations in a Long-Horizon Model







For more information, see our website at http://eea.epri.com

© 2017 Electric Power Research Institute, Inc. All rights reserved.

Modeling of SCC Pricing of Power Sector CO_2

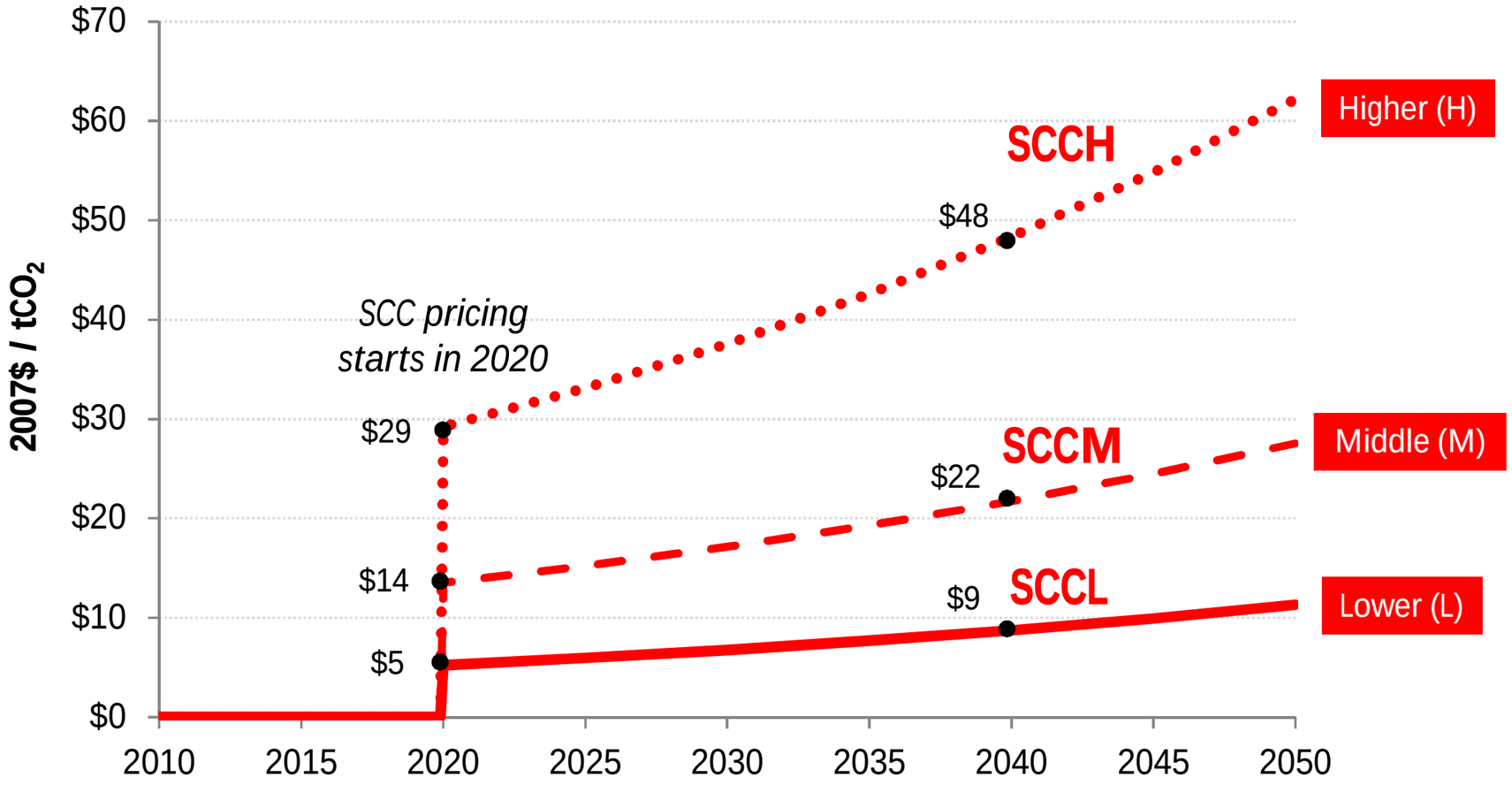
- Main scenarios: Apply SCC to power-sector-only CO_2 emissions in individual U.S. regions
  - Apply various SCC price paths to just one region
  - Sensitivity scenario constraining additional power imports
- Other scenarios
  - National SCC
  - No new transmission
  - Inelastic demand

Region	SCC Trajectory	Import Constraint
Region X	None	No
Region X	SCCL (lower)	No
Region X	SCCM (middle)	No
Region X	SCCH (higher)	No
Region X	SCCL (lower)	Yes
Region X	SCCM (middle)	Yes
Region X	SCCH (higher)	Yes

Import Constraint = in SCC region, prohibit increases in electricity imports above reference levels

© 2017 Electric Power Research Institute, Inc. All rights reserved.

SCC Pricing Assumptions



SCC prices source: Anthoff et al. (2011)

© 2017 Electric Power Research Institute, Inc. All rights reserved.

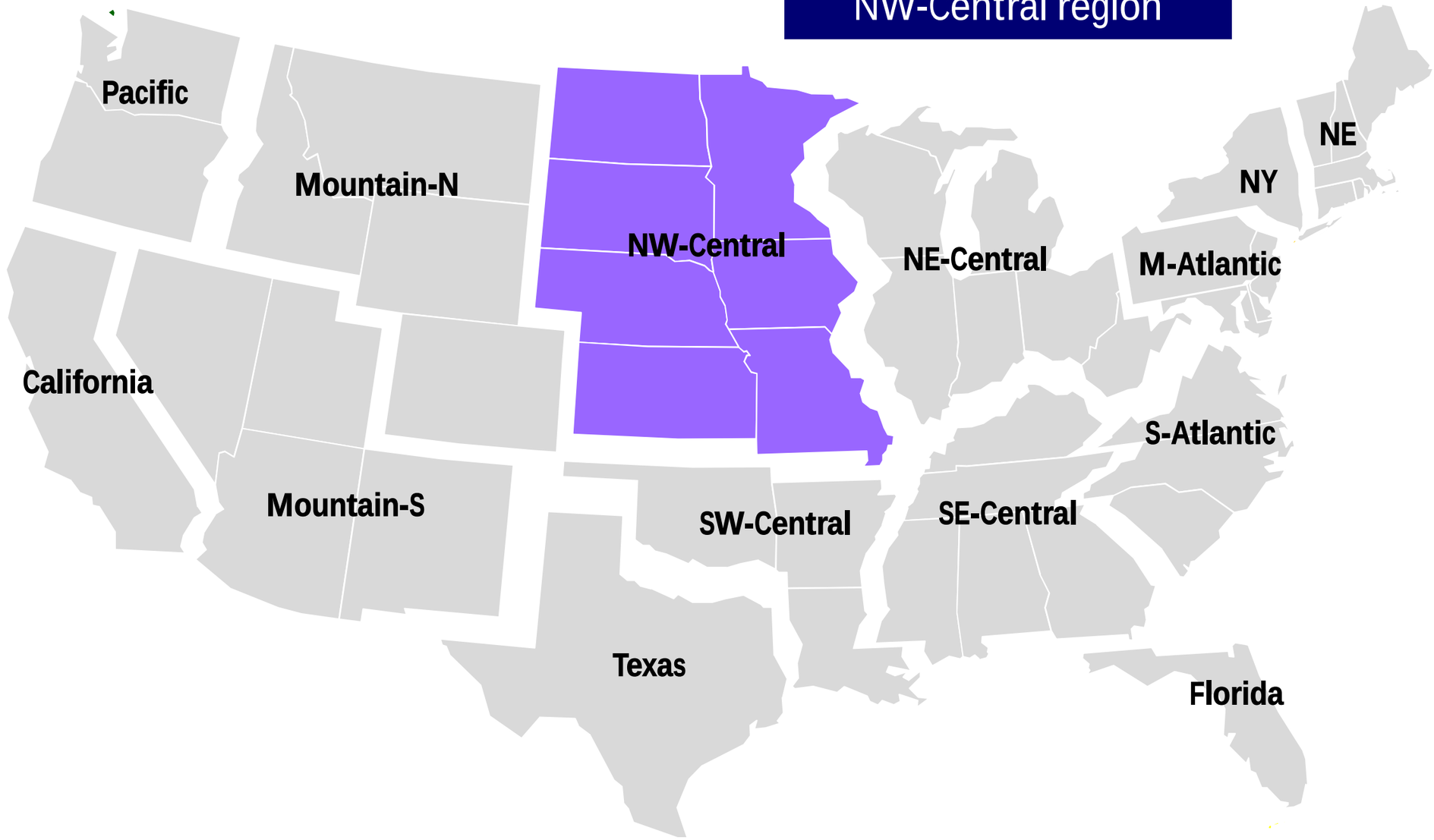
Detailed Regional Results

NW-Central Region

© 2017 Electric Power Research Institute, Inc. All rights reserved.

US-REGEN Default Regions

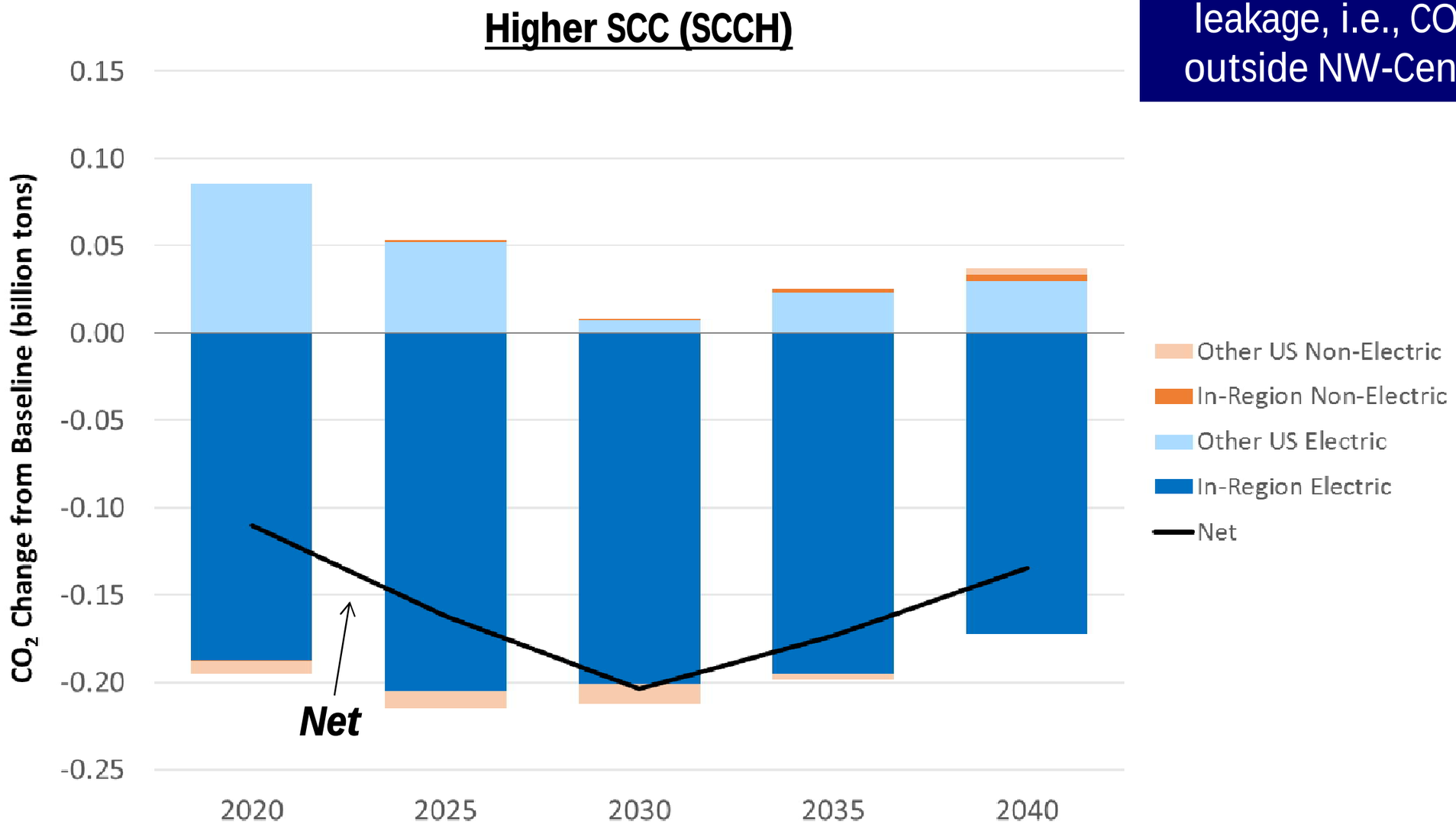
Applying SCCs to the NW-Central region



© 2017 Electric Power Research Institute, Inc. All rights reserved.

Economy-Wide CO_2 Changes

Model results indicate leakage, i.e., CO_2 changes outside NW-Central Power

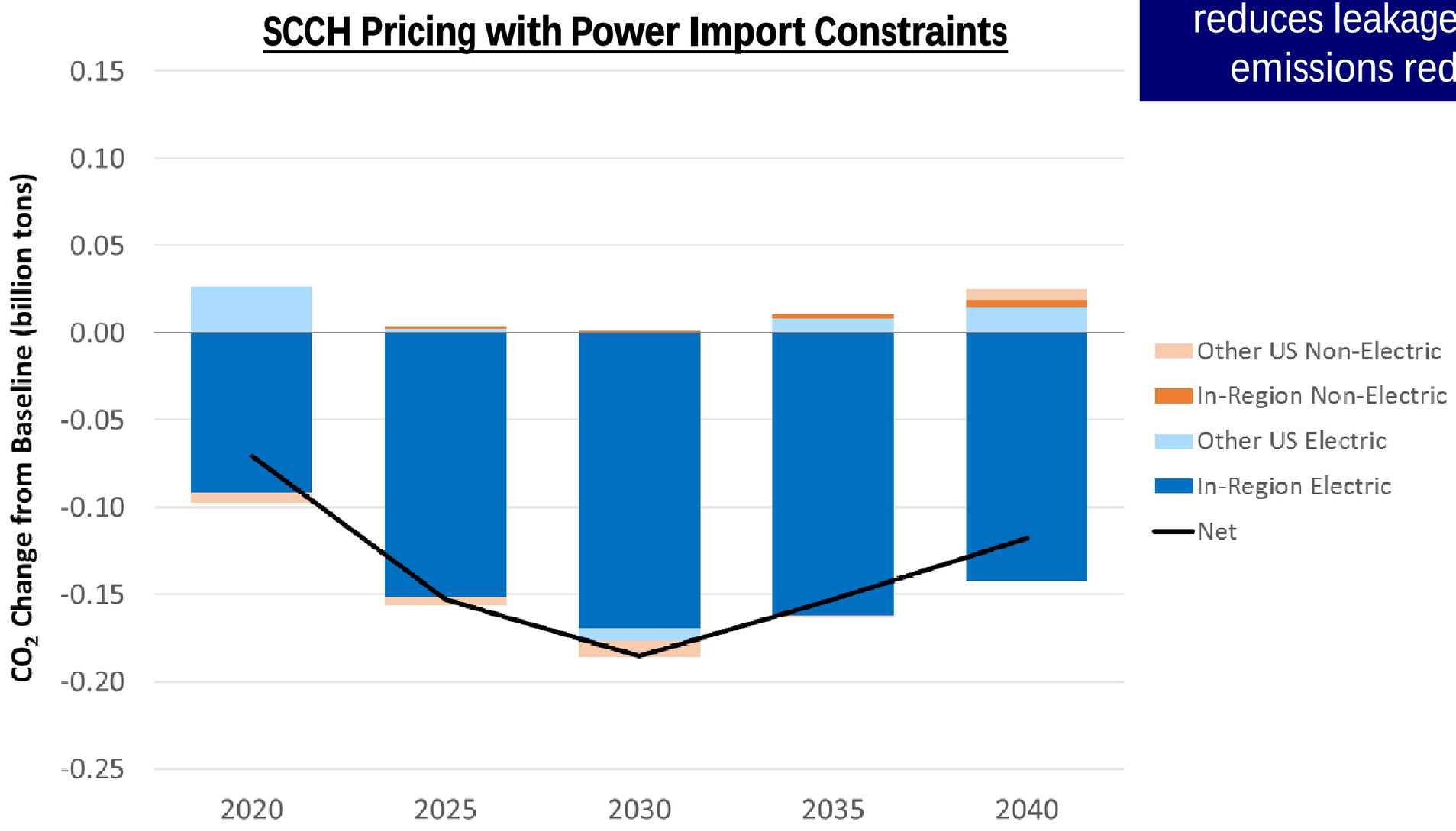


© 2017 Electric Power Research Institute, Inc. All rights reserved.

EPRI ELECTRIC POWER RESEARCH INSTITUTE

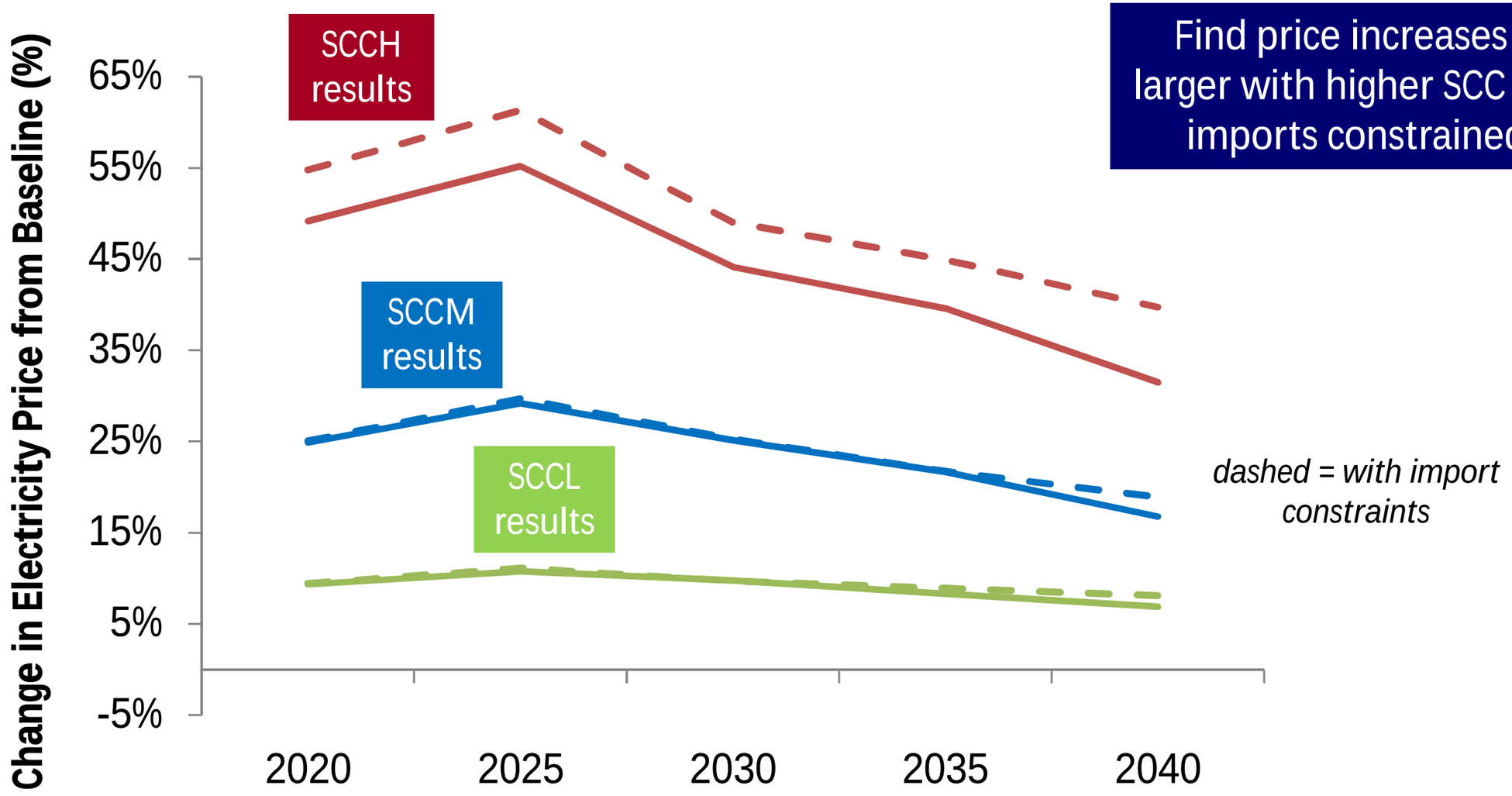
Economy-Wide CO_2 Changes

Constraining power imports reduces leakage, AND net emissions reductions



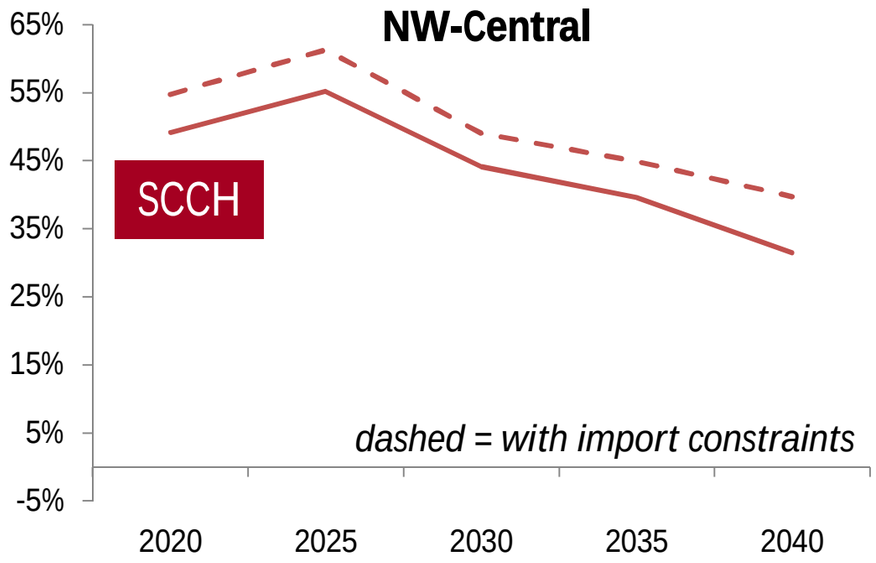
© 2017 Electric Power Research Institute, Inc. All rights reserved.

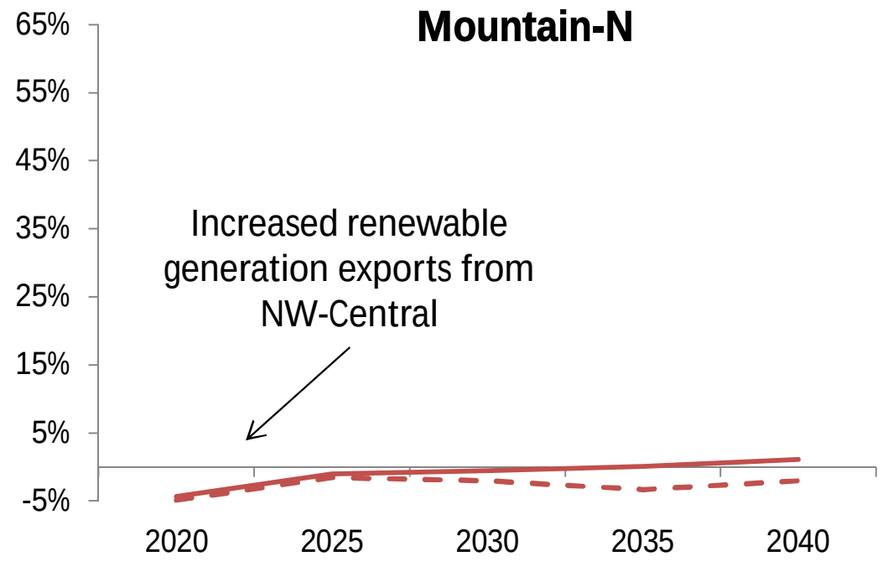
NW-Central Electricity Price Changes

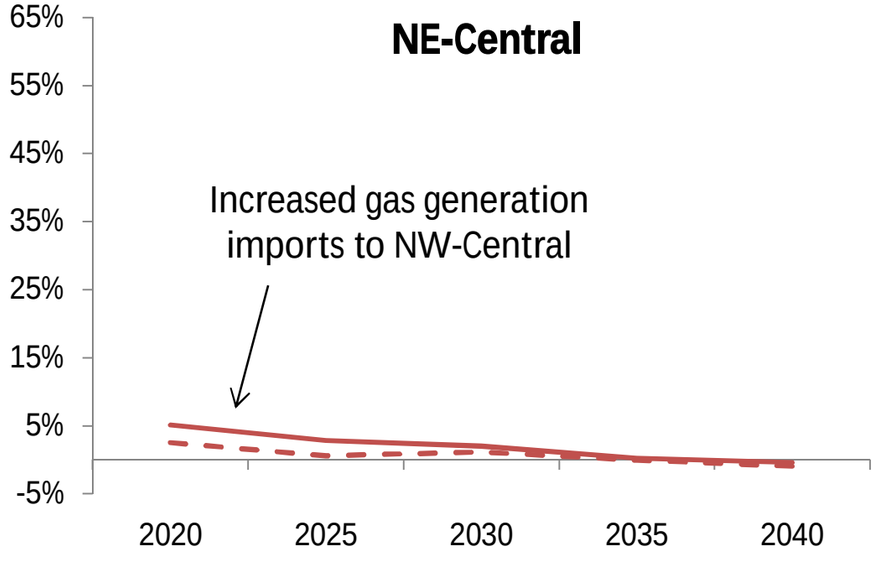


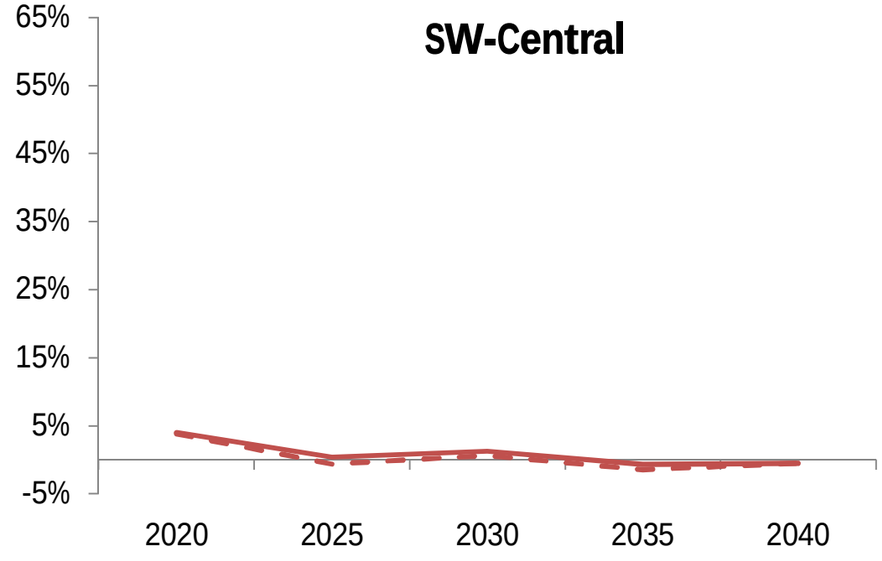
© 2017 Electric Power Research Institute, Inc. All rights reserved.

Electricity Price Changes Beyond NW-Central





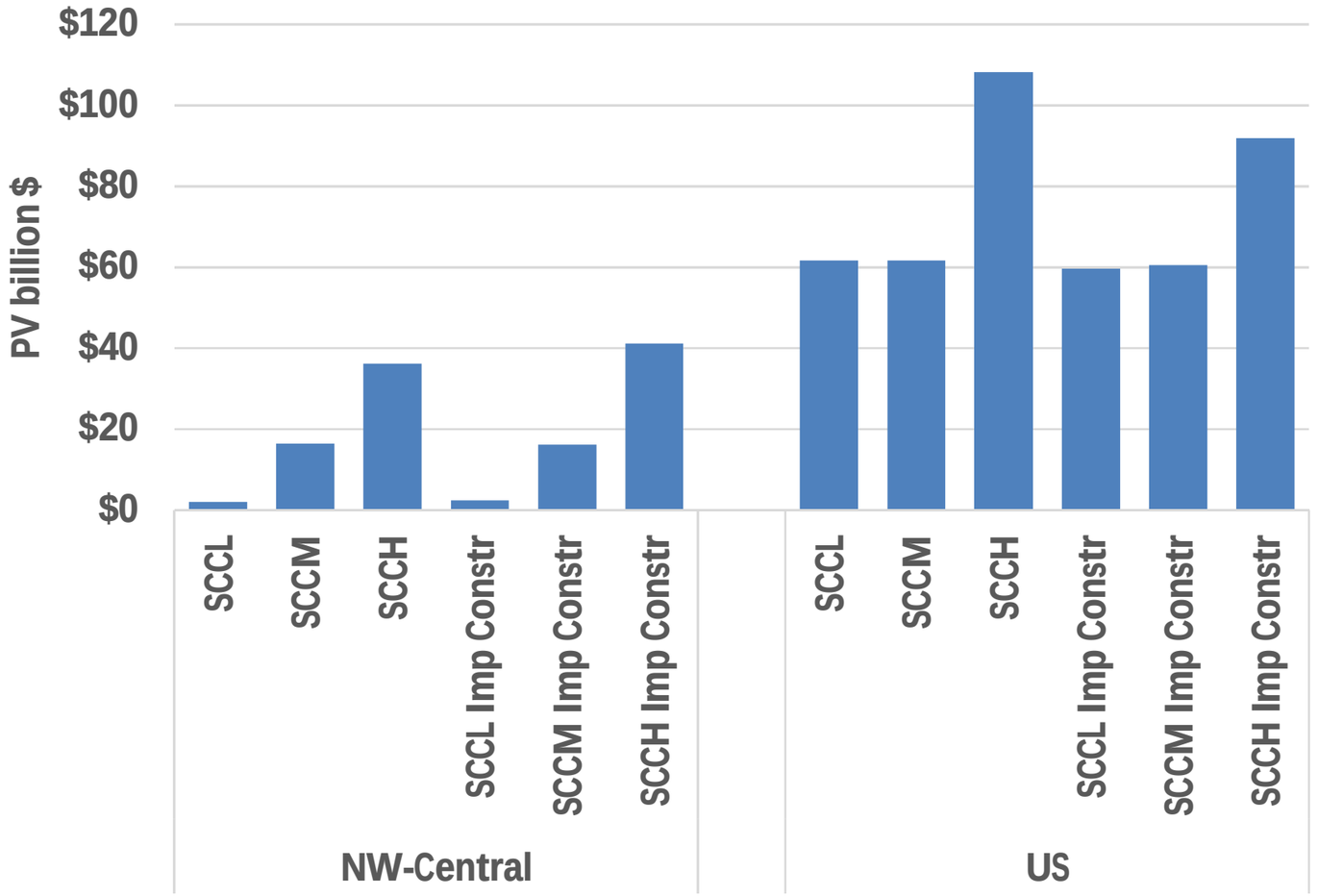




© 2017 Electric Power Research Institute, Inc. All rights reserved.

Macroeconomic Implications

Net present value consumption loss through 2050 with NW-Central SCC pricing policies for the NW-Central region (left) and the entire U.S. (right)



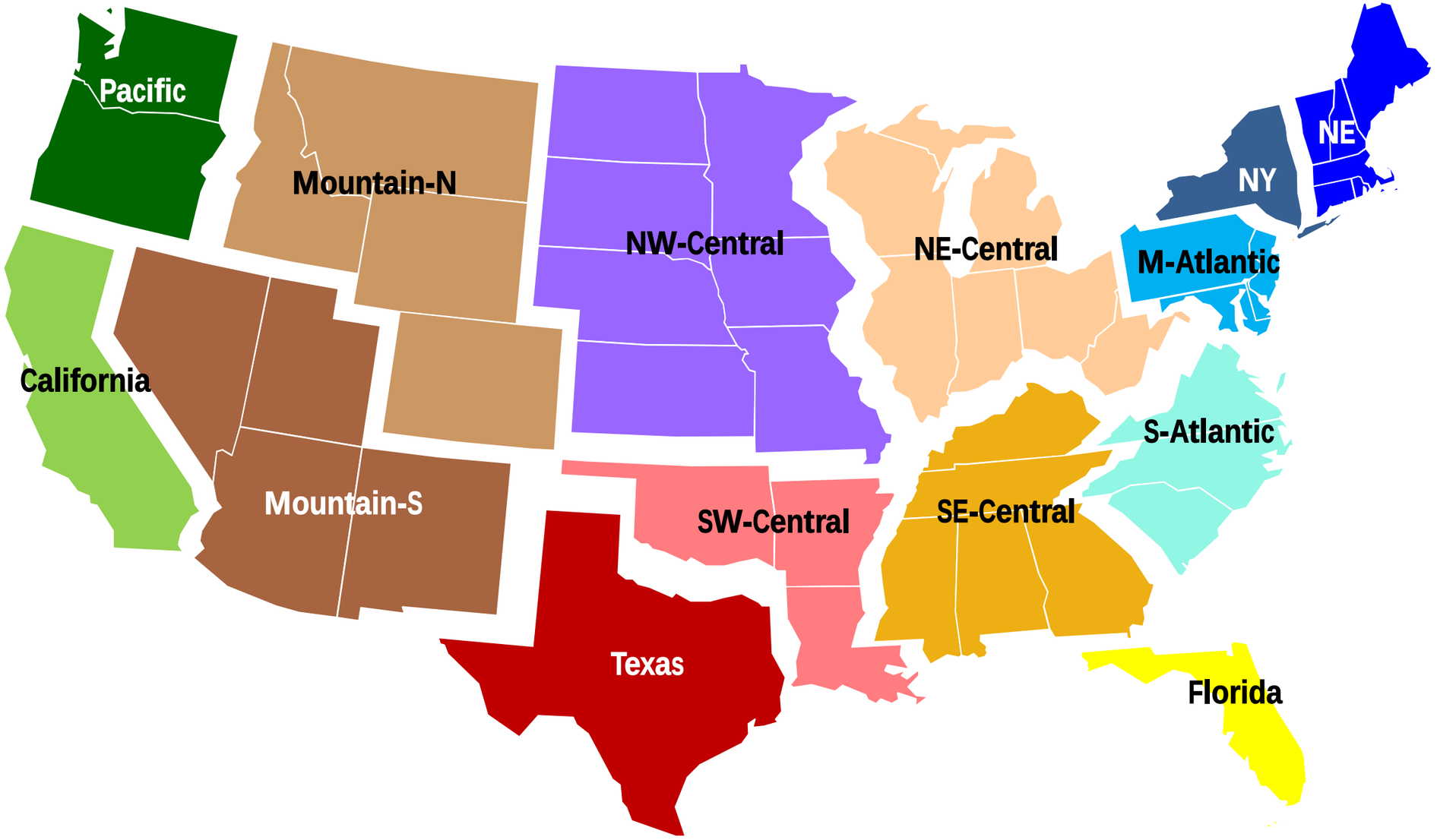
Find broader economic implications (in region and outside) – power production costs, macroeconomic costs

© 2017 Electric Power Research Institute, Inc. All rights reserved.

Cross-Region Results

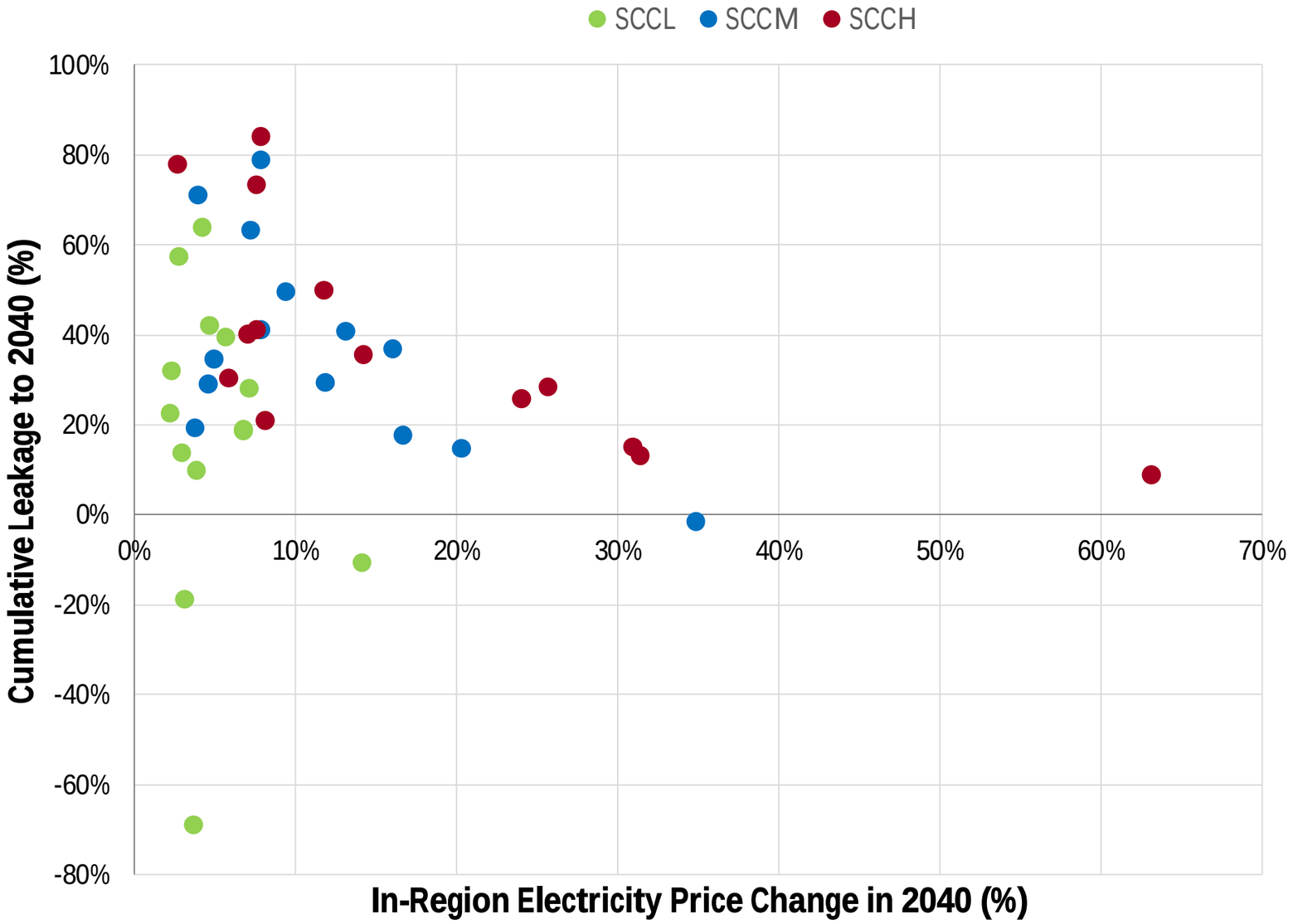
© 2017 Electric Power Research Institute, Inc. All rights reserved.

US-REGEN Regional Map



© 2017 Electric Power Research Institute, Inc. All rights reserved.

Leakage and Electricity Price Changes

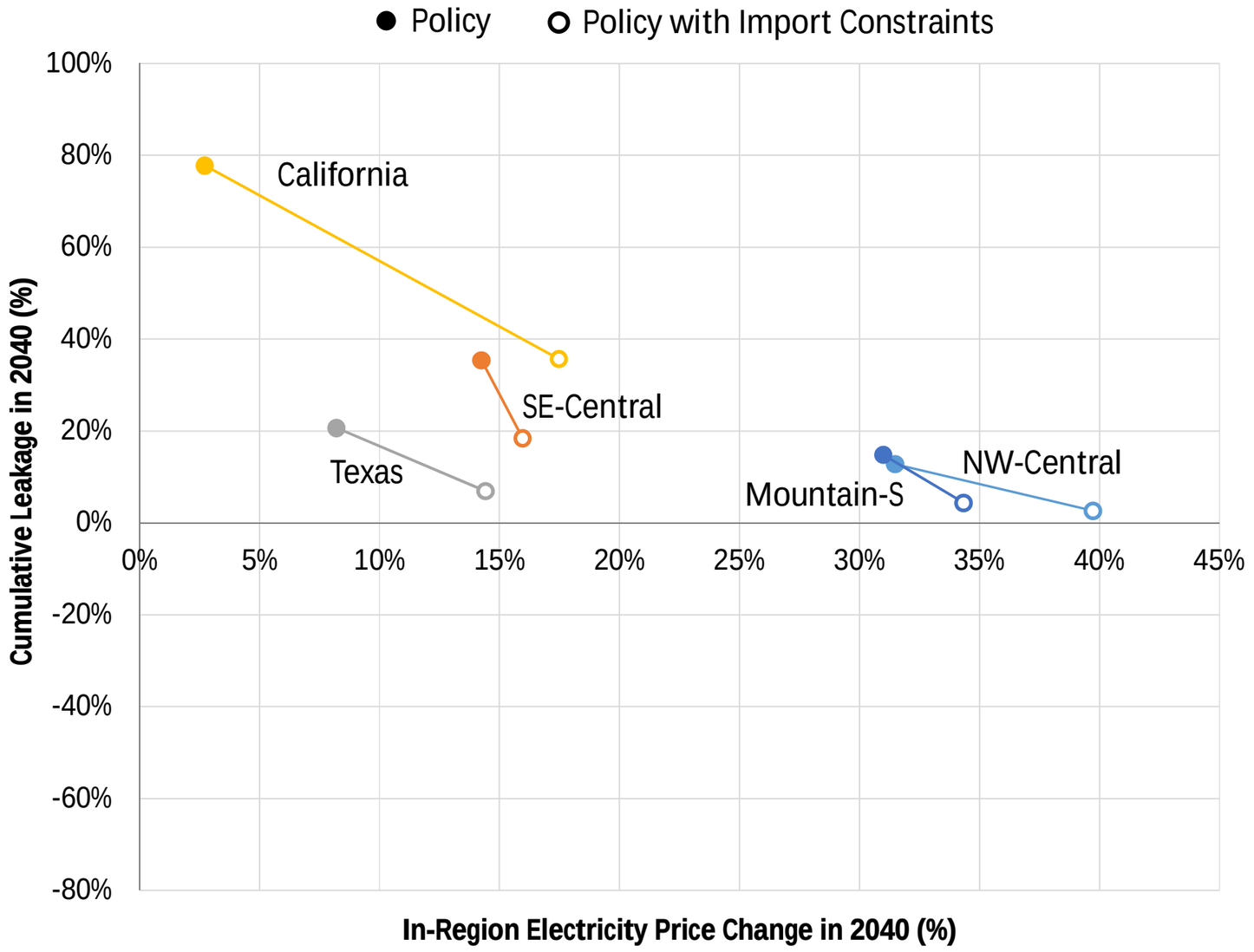


Observations

- CO_2 leakage occurring and varies by region, with positive leakage (i.e., higher emissions) in most regions and SCC trajectories
- Electricity prices increase as well with regional variation
- Leakage and price changes typically increase in the SCC, but not always

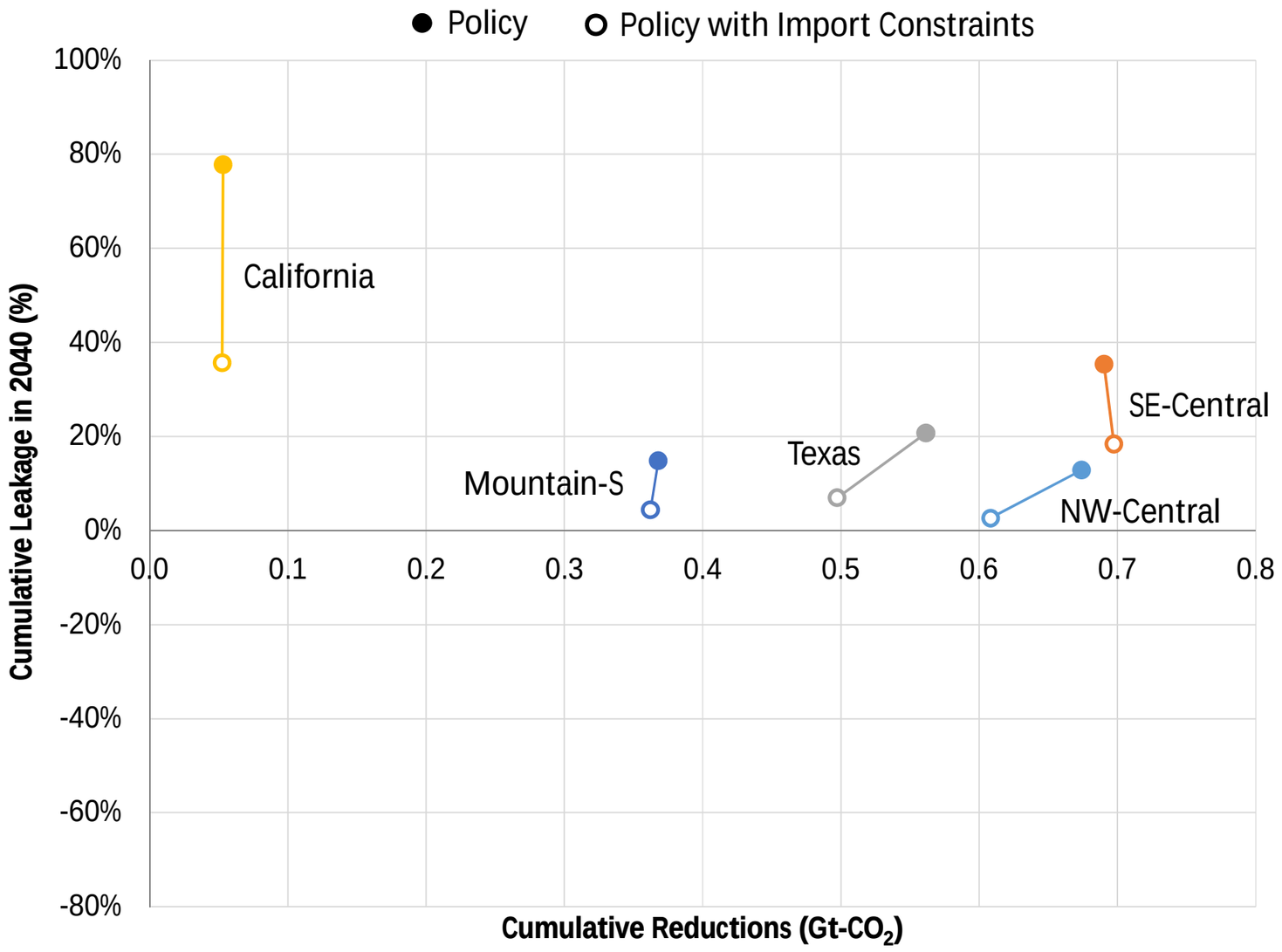
© 2017 Electric Power Research Institute, Inc. All rights reserved.

Import Constraints: Leakage and Electricity Prices (SCCH)



© 2017 Electric Power Research Institute, Inc. All rights reserved.

Import Constraints: Leakage and Net Reductions (SCCH)

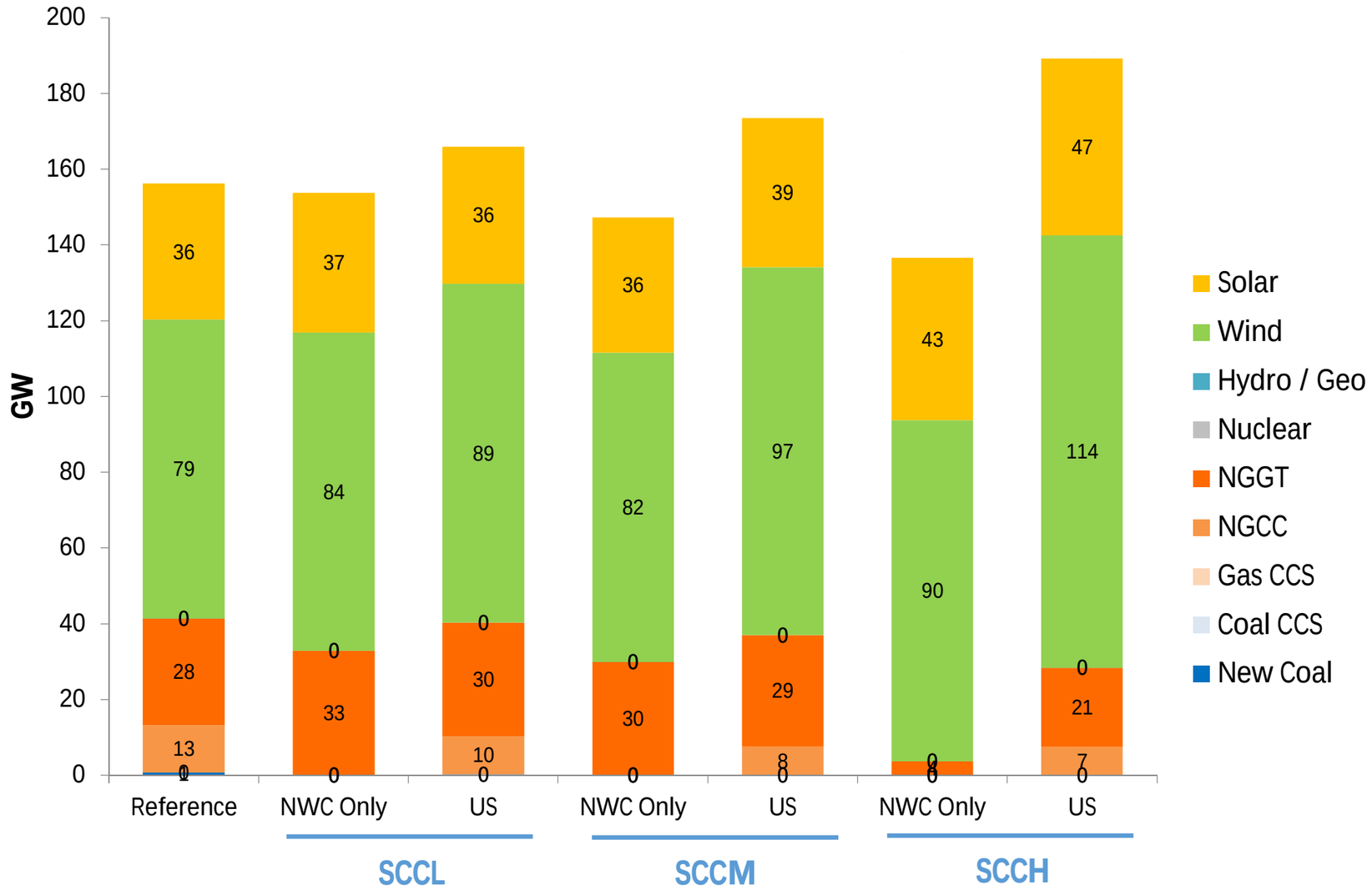


© 2017 Electric Power Research Institute, Inc. All rights reserved.

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Comparison of Regional and National SCC Pricing

Cumulative Additions in NW-Central to 2050



Summary of Additional Sensitivities

- National power-sector SCC pricing
  - Cumulative fuel market leakage of 1–3%
  - Policies in neighboring regions can materially impact capacity planning decisions [left figure]
- Higher leakage rates possible when new transmission is constrained and when electricity demand is less price responsive

© 2017 Electric Power Research Institute, Inc. All rights reserved.

Primary Insights from the SCC Pricing Analysis

CO_2 leakage potential

- CO_2 leakage is possible within and outside the electric sector that would affect CO_2 reduction benefits
- Benefits calculations that ignore leakage would be incorrect – too high if there is positive leakage, and too low if there is negative leakage

Price effects and policy costs

- Electricity price changes are possible within and across regions that would affect consumers
- Electric sector and macroeconomic costs are also possible within a region and nationally

Potential leakage management: constraining power imports into the SCC pricing region (or pricing CO_2 imports) likely reduces leakage, but also results in larger price increases and lower net CO_2 reductions

Effects vary: by region, time, policy stringency, policy design (e.g., leakage mitigation provisions), policy environment in neighboring regions, and price responsiveness of demand

Overall insights: CO_2 leakage is possible when there are differences in regional power sector CO_2 policy stringency; additional environmental and economic metrics are important to consider

© 2017 Electric Power Research Institute, Inc. All rights reserved.

Thank you for joining us today!

We hope you'll join us for our September 5th SCC Webcast

- July 25, 2017 (1:30-3 pm EDT)
  - *Understanding the Social Cost of Carbon: A Model Diagnostic and Inter-Comparison Study*
- August 16, 2017 (2-3 pm EDT)
  - *Social Cost of Carbon Pricing of Power Sector CO_2: Accounting for Leakage and Other Social Implications from Subnational Policies*
- September 5, 2017 (2-3 pm EDT)
  - *Applying the Social Cost of Carbon: Technical Considerations*

Publications and slides available at http://eea.epri.com ("Research" tab). For information: Steven Rose, srose@epri.com.

© 2017 Electric Power Research Institute, Inc. All rights reserved.

Bibliography

- Bistline and Rose (submitted), "Social Cost of Carbon Pricing of Power Sector CO_2: Accounting for Leakage and Other Social Implications from Subnational Policies," EPRI Discussion Paper
- Rose and Bistline (2016), Applying the Social Cost of Carbon: Technical Considerations, EPRI Report 3002004659, http://epri.co/3002004659.
- Rose, et al. (2014), Understanding the Social Cost of Carbon: A Technical Assessment, EPRI Report 3002004657, http://epri.co/3002004657.
- Rose, et al. (2017), "Understanding the Social Cost of Carbon: A Model Diagnostic and Inter-Comparison Study," *Climate Change Economics* **8(2)**
- EPRI (2017), US-REGEN Model Documentation, EPRI Report 3002010956
- Blanford, et al. (2016), Simulating Annual Variation in Load, Wind, and Solar by Representative Hour Selection, EPRI Report 3002008653

For more information, see our website at http://eea.epri.com

© 2017 Electric Power Research Institute, Inc. All rights reserved.

Together…Shaping the Future of Electricity

John Bistline
Senior Technical Leader
650-855-8517
jbistline@epri.com

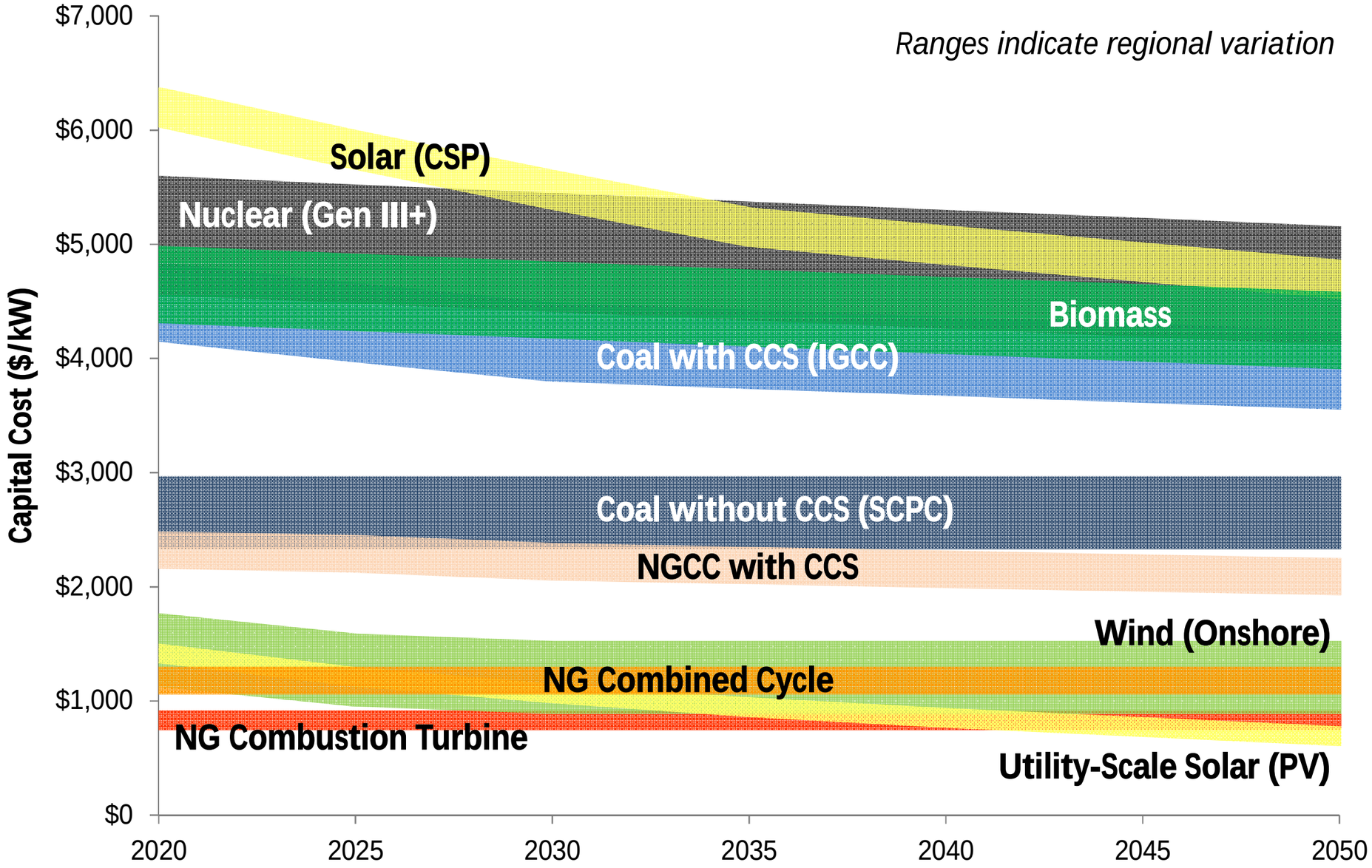
© 2017 Electric Power Research Institute, Inc. All rights reserved.

Explaining Region-Specific Leakage Variation

- Two primary factors determine leakage and reliance on imports under regional SCC pricing
  1. Relative regional prices (at the load segment level)
  2. Relative regional CO_2 emission intensities of electricity (CO_2/MWh)
     - In SCC region: higher CO_2 intensity ➔ higher electricity price
     - Outside SCC region: higher CO_2 intensity ➔ higher import CO_2 rate
- Other factors include own-price elasticities, transmission
- Factors vary by region and interact

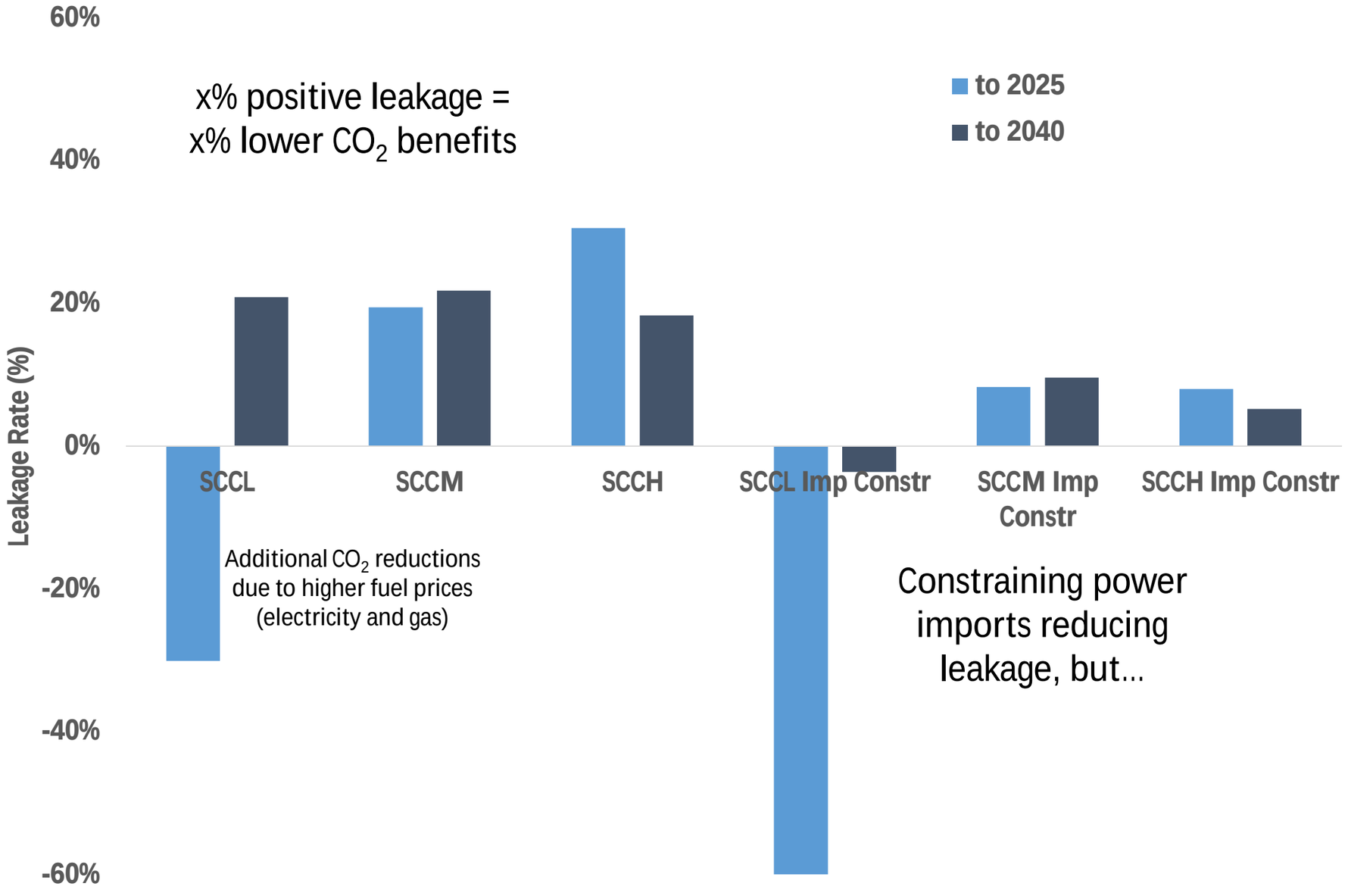
© 2017 Electric Power Research Institute, Inc. All rights reserved.

US-REGEN Assumed Capital Cost Trajectories



© 2017 Electric Power Research Institute, Inc. All rights reserved.

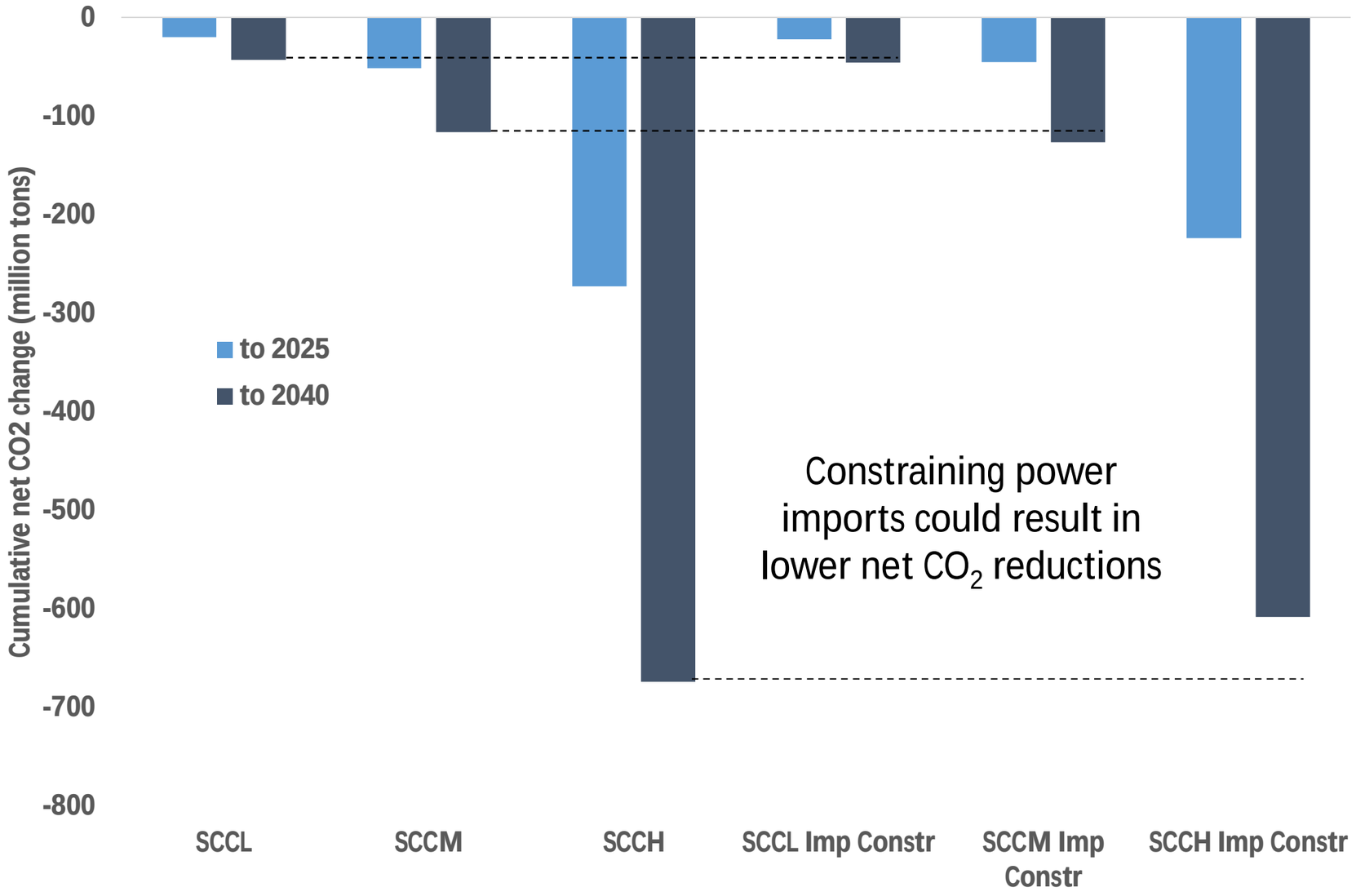
NW-Central Cumulative CO_2 Leakage Rates



© 2017 Electric Power Research Institute, Inc. All rights reserved.

EPRI ELECTRIC POWER RESEARCH INSTITUTE

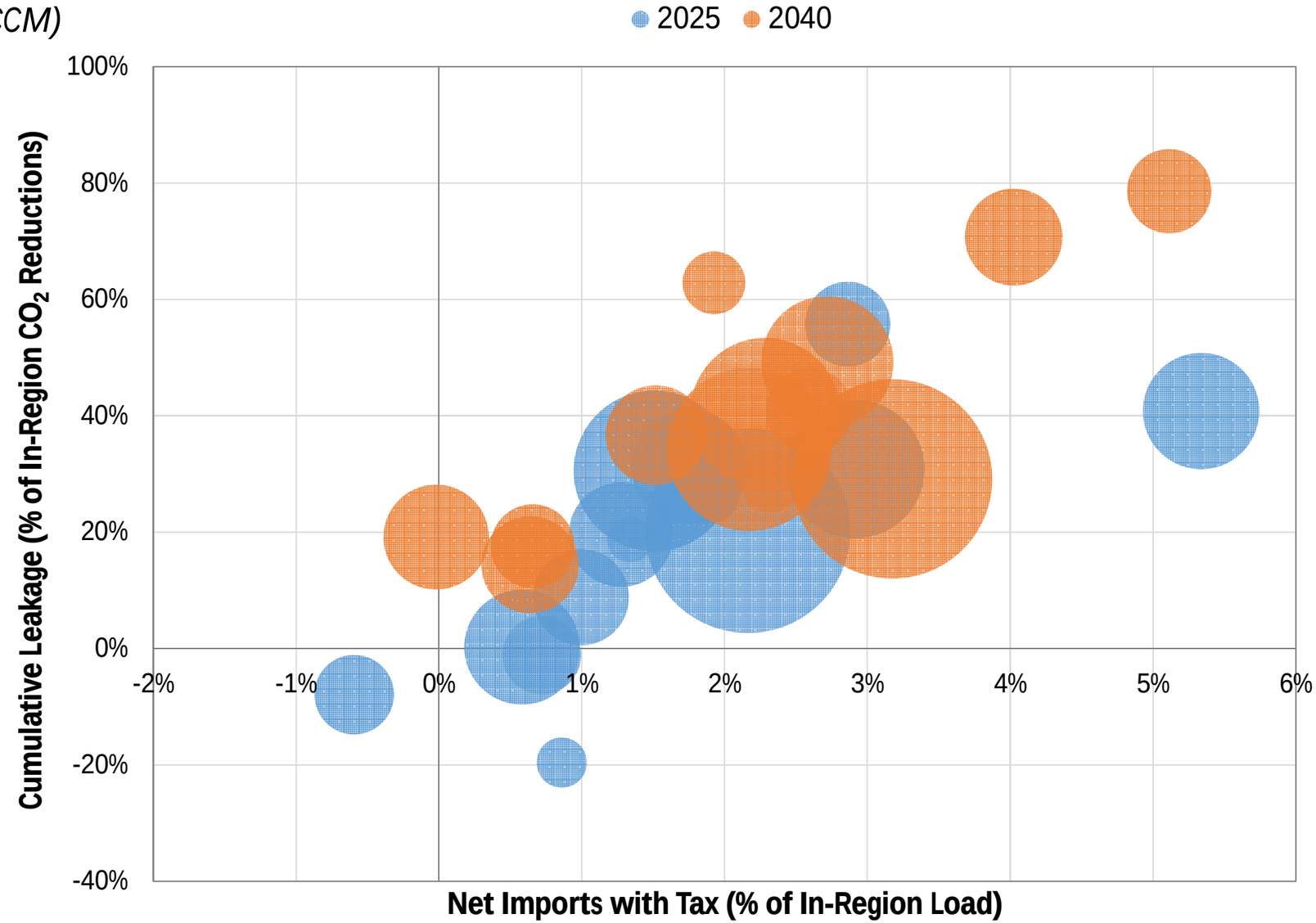
Cumulative Net CO_2 Reductions with NW-Central SCC



© 2017 Electric Power Research Institute, Inc. All rights reserved.

Link between Leakage and Trade

Middle SCC Values (SCCM)

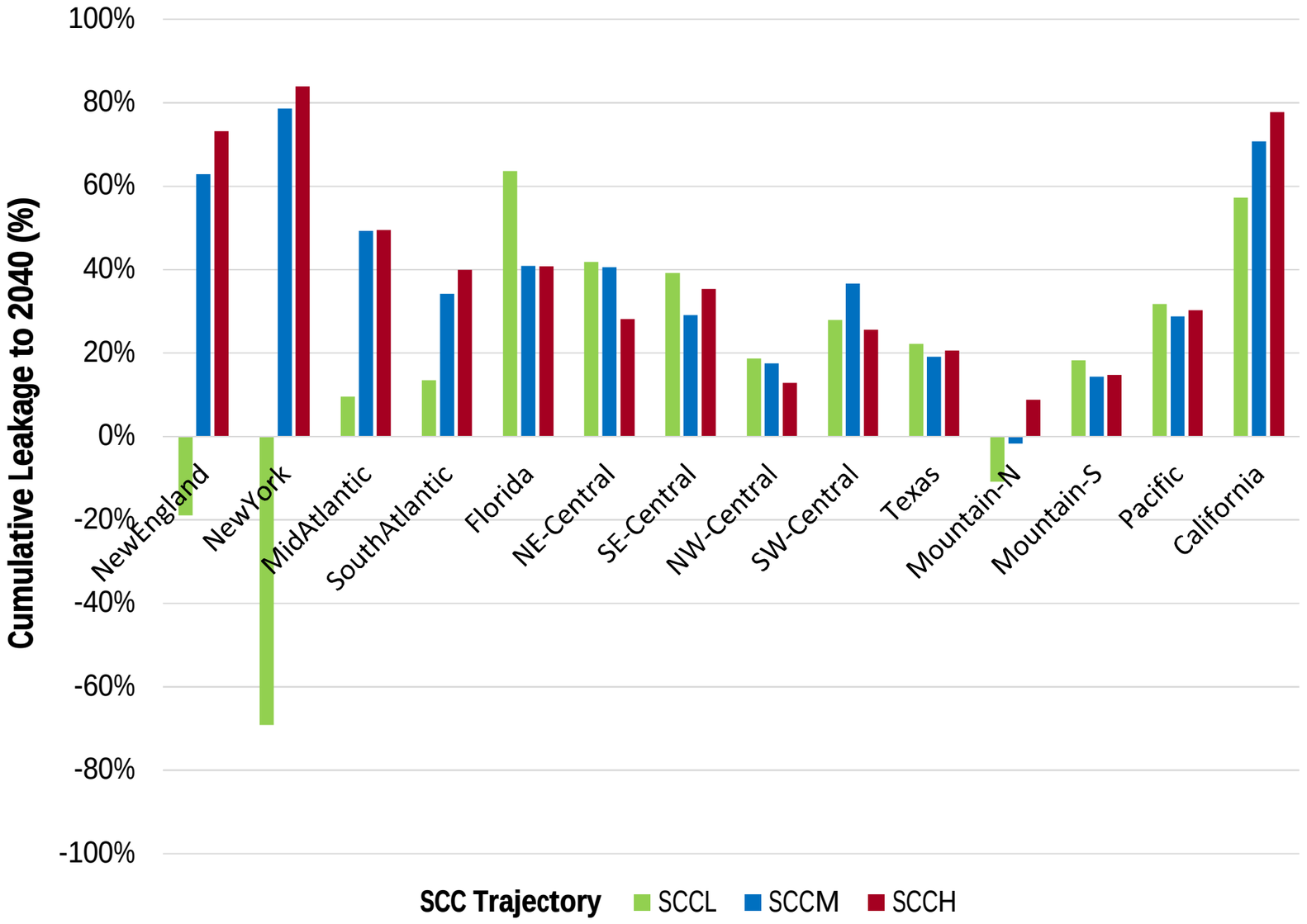


size of bubble = in-region emissions reduction

© 2017 Electric Power Research Institute, Inc. All rights reserved.

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Leakage and Policy Stringency across Regions



© 2017 Electric Power Research Institute, Inc. All rights reserved.

EPRI ELECTRIC POWER RESEARCH INSTITUTE