Carbon Pricing & Leakage Mitigation Study Comparisons

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Objective

- Provide additional context for modeling impacts of carbon pricing & leakage mitigation mechanisms
- Compare:
  - Key Study Questions
  - Modeling of Carbon Pricing
  - Modeling of Leakage Mitigation
  - Key Findings

Recent Studies & Analysis*

Presented at CPSTF:

- PJM: Study of Carbon Pricing & Leakage Mitigation Mechanisms
- MJB&A / EDF: Carbon Pricing Modeling
- Monitoring Analytics: Carbon Pricing in PJM
- Exelon: Using Energy Markets to Enhance RGGI, RTO Leakage Mitigation for Carbon Reduction
- Vistra Energy: Regional Carbon Pricing as Leakage Mitigation for Subregional Carbon Pricing
- E3 / EPSA: Least Cost Carbon Reduction Policies in PJM

Additional:

- ICF / VA DEQ: Virginia Greenhouse Gas Rule
- ICF / PA DEP: Pennsylvania RGGI Modeling Report
- Resources for the Future (RFF):
  - State Policy Options to Price Carbon from Electricity
  - Options for Issuing Emissions Allowances in a Pennsylvania Carbon Pricing Policy

* This is not intended to be a complete list of studies on this topic.
Each study included in the comparison focuses on the PJM region.

Key Study Questions

PJM	Impact of carbon prices and leakage mitigation via border adjustment constraints applied in different regions of PJM on generation dispatch, emissions, LMP & system production cost.
EDF / MJB&A	Impact of various RGGI state, emissions budget, allowance payment, leakage mitigation, and ZEC payment scenarios on CO_2 emissions, generation mix, electricity flows, allowance prices, and system costs.
Monitoring Analytics	Impact of carbon prices on short run marginal cost and LMP. Comparison of carbon allowance revenue to RPS costs.
Exelon	Impact of leakage mitigation on RGGI.
Vistra	Would addressing leakage via a mechanism mimicking regional carbon pricing insulate Non-RGGI states from impacts of sub-regional carbon pricing on consumer cost (increased energy, ZEC payments)?
E3 / EPSA	Implications of carbon reduction policy options in PJM, and least cost resource portfolios and hourly system dispatch under each policy. What are the resource portfolio needs, resulting system costs, and associated system emissions?
ICF / VA DEQ	Impact of proposed RGGI cap on generation and emissions of covered sources, and cost to VA consumers.
ICF / PA DEP	Impact of joining RGGI on PA power sector and overall economy with and without investing RGGI proceeds.
RFF	• Impact of state-only, regional and RGGI linking. Impact of policy options such as a declining cap, cost containment and investment of allowance proceeds on results. • Impact of allowance allocation methodology for a PA carbon cap linked with RGGI: Compared distribution of allowance value to general fund, electricity consumers and electricity producers.

Modeling of Carbon Pricing

Carbon Price | **Carbon Cap → Carbon Price**

PJM	Applied carbon prices sub-regionally & regionally. Modeled low & high RGGI price points based on RGGI ECR ($6.87/ton) & CCR ($14.88/ton). High carbon prices sensitivities included ($25/ton & $50/ton).
EDF / MJB&A	Cap and trade system with emission budget levels for a RGGI/RGGI-like trajectory and a deep decarbonization trajectory, applied sub-regionally. Scenarios with unlimited allowance trading within capped region & in-state only allowance trading in certain states.
Monitoring Analytics	Regionally applied carbon pricing ($5, $10, $15 per ton) on the marginal units' offer prices to estimate impact on LMP (not based on a counterfactual redispatch of the system). Analyzed carbon price implied by REC and SREC prices.
Exelon	All RGGI generators have carbon costs built into their bids; non-RGGI generators do not.
Vistra	Regional and sub-regional carbon prices.
E3 / EPSA	Represented RGGI via carbon prices starting at today's price of around $6/tonne and escalated annually at same 7% escalator as "soft cap."
ICF / VA DEQ	Cap and trade scenarios with and without VA participation in RGGI.
ICF / PA DEP	Cap and trade scenarios with and without PA participation in RGGI. Policy scenarios for investment of allowance revenues.
RFF	Cap and trade assuming elements of the RGGI 2016 Program Review (completed in 2017) effective in 2021 are fully implemented (caps, ECR, CCR). Policy scenarios varied by allowance allocation approach, linkage of additional states to RGGI, and addition of a renewable technology standard.

Modeling of Leakage Mitigation

	Leakage Mitigation	No Leakage Mitigation
PJM	Border adjustment constraints within security constrained economic dispatch. Scenarios with a one-way border adjustment account for impacts of carbon price transfers in to the carbon pricing region. Scenarios with a two-way border adjustment account for impacts of carbon price transfers in to the carbon pricing region and transfers from the carbon pricing region.	
EDF / MJB&A	Leakage mitigation via reducing a state or region emissions allowance cap by the amount of emissions tagged to importing generation. Variations: No leakage mitigation, applied to entire capped area, or applied to selected states only.	
Monitoring Analytics		None
Exelon	Border adjustments similar to NYISO proposal: Add carbon cost to electricity flowing from non-RGGI to RGGI within PJM. Did not remove carbon cost from exported electricity from RGGI states as generation maintains compliance obligation under RGGI regardless of where load is served.	
Vistra	Regional carbon pricing approach in which all generators subject to emission-based compliance cost; if they don't actually face the cost then the design isn't incentive-compatible (resources will adjust offers to get around it). Results in a pool of Non-RGGI generator compliance payments.	
E3 / EPSA		None
ICF / VA DEQ		None
ICF / PA DEP	Allowance allocation, revenue investment in energy efficiency, clean & renewable energy, GHG abatement, direct bill assistance, and PA general fund.	
RFF	Allowance allocation, revenue investment. Compared output-based vs energy efficiency / retail rate relief.	

Key Findings

	Carbon Pricing	Leakage Mitigation
PJM	• Shifts in generation production from carbon price sub-region to rest of RTO. Emitting resources impacted by shifts are driven by generation mixes of each sub-region. • Emissions decrease in carbon price sub-region, increase in rest of RTO. Net RTO impact based on states included in carbon price sub-region. The more emitting generation in the carbon price sub-region, the larger the net RTO emissions reductions. • LMPs & system production cost increase in sub-regional and regional carbon pricing scenarios	• Border adjustments result in generation shifts from rest of RTO to the carbon price sub-region. Net RTO emissions vary based on states in carbon price sub-region. • Resource shuffling contributes to smaller shift observed with one-way border adjustment: Resources with zero / low carbon emissions are associated with transfers into carbon price sub-region while resources with high emissions are not, and not exposed import cost. • Two-way border adjustment scenarios mirror counterfactual scenarios with no carbon price. • Decrease in LMP & system production cost. Larger decrease with two-way border adjustment than one-way border adjustment, which saw small not no decrease depending on scenario.
EDF / MJB&A	• Allowance prices remain low through 2030 under most RGGI consistent trajectories • Linking with RGGI helps achieve states' environmental objectives and supports existing nuclear fleet. • Nuclear and gas-fired generation output levels are highly sensitive to capped area, cap trajectory, and leakage mitigation measure. Coal output declines in all scenarios. • All scenarios result in positive net emission reduction.	• Effective leakage mitigation and more ambitious emission caps (in line with deep decarbonization trajectories) provide benefits for the existing nuclear fleet and support solar new builds. • Leakage mitigation results in lower overall emission (larger "leakage mitigated" areas produce greater reductions).
Exelon	RGGI is a proven model for aligning state carbon reduction goals with the efficiency of RTO markets. Leakage undermines use of energy markets for desired emissions reductions from electricity generation.	Border adjustments preserve efficiencies of regional energy markets, preserve state policy choices and reduce emissions regionwide.
Vistra	• Leakage impedes subregional carbon pricing from achieving meaningful emissions reductions. • Regional carbon pricing would achieve significant emissions reductions at the same carbon price.	• Non-RGGI states would accumulate pool of compliance revenues. Regional Carbon Pricing would shift some generation back to RGGI states, and increase RGGI allowance revenues. Incremental revenues can cover increased costs to Non-RGGI customers. • Nuclear resources (in RGGI and Non-RGGI states) currently receiving ZECs would see an increase in competitive market revenue, decreasing ZEC payments

Key Findings (continued)

	Carbon Pricing	Leakage Mitigation
Monitoring Analytics	A consistent carbon price in the PJM region would be the most efficient way to implement a social decision to limit carbon. The use of inconsistent implied carbon prices by states is inconsistent with an efficient market and inconsistent with the least cost approach to meeting state environmental goals.	
E3 / EPSA	• Policies that regulate carbon directly result in the lowest-cost emissions reductions. • A regionwide, technology-neutral Clean Energy Standard (CES) approaches the efficiency of a direct carbon policy in achieving low-cost emissions reductions. • Renewable resources play a significant role in decarbonizing the PJM system in all scenarios. • Current clean energy policies are costly and ineffective at reducing carbon emissions.	Expansion of RGGI to all PJM states is another approach that would eliminate leakage and improve the effectiveness of this program at reducing GHG emissions.
ICF / VA DEQ	• RGGI allowance prices remain low, from $4/ton in 2022 to $5.50/ton in 2030 • Under the policy case imports increase in VA and in RGGI as a whole.	N/A
ICF / PA DEP	• RGGI allowance prices remain low, and decline in later years.	• Allowance revenue investment in PA results in reduction in conventional generation, increase in renewable generation, and smaller decline in total generation compared to the policy case. • Similar trends across PJM for conventional and renewable generation; however, total generation increases rather than declines, in part due to generation increase in VA.
RFF	RGGI allowance prices remain low. In study focused on PA, emissions leakage is moderate.	Broader study: Output-based allocation, while resulting in an increase in emissions from covered sources ultimately results in a reduced leakage, and the least amount of emissions across the region. PA study: Output-based allowance allocation to electricity producers mitigates leakage.

Common Threads

- Studies that model RGGI cap and trade indicate RGGI prices will remain low, closer to program price floor, as additional states link to RGGI.
- Carbon pricing contributes to cost-efficient emissions reductions that increase with broader scope of application and magnitude of carbon price.
- There are many approaches to leakage mitigation:
  1. Applying carbon pricing regionally
  2. Border adjustment constraints within wholesale electricity markets (one-way or two-way)
  3. Adjusting state RGGI allowance caps based on emissions of imports
  4. RGGI allowance allocation & revenue investment to provide incentives for in-state generation & energy efficiency
- Impact of leakage mitigation varies based on the mechanism and factors like:
  - Resources in carbon price sub-region
  - Amount of net imports or exports from the carbon price sub-region