



Expanded Results of PJM Study of Carbon Pricing & Potential Leakage Mitigation Mechanisms

Carbon Pricing Senior Task Force
February 25, 2020

July 2019 Meeting:
Reviewed objectives
and proposed
assumptions for the
PJM Carbon Study

**January 2020
Meeting:**
Reviewed objectives
and initial modeling
results

Today:
Review objectives and
additional scenarios
taking into account
stakeholder feedback

PJM is studying the potential impacts of a carbon price and potential leakage mitigation mechanisms in order to inform stakeholders and policy-makers.

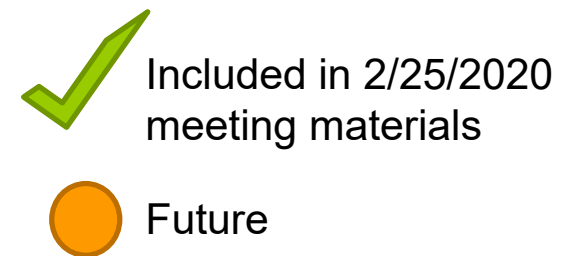
- PJM is **not** proposing to establish a carbon price.
- PJM is conducting this study to inform carbon pricing discussions in the CPSTF stakeholder process.
- Feedback on **initial & extended modeling** will be used to guide additional modeling efforts.
- Policy-makers in the PJM region are ultimately responsible for environmental policy, and any associated revenue generated through its application.

Modeling Sensitivities

1. Addition of VA to Carbon-Price Sub-Region ✓
2. Addition of VA & PA to Carbon-Price Sub-Region ✓
3. Addition of PA to Carbon-Price Sub-Region ●
4. All of PJM included in Carbon-Price Sub-Region ●
5. Higher carbon prices ●

Additional Data Points & Clarifications

1. Additional information on border adjustment equations & modeling ✓
2. Impact of border adjustments on production cost ✓
3. Impact of border adjustments on uplift ●
4. Additional information on external interchange ✓
5. Results by state, zone ●



Results depend on the generation mix, and emissions intensities, of each sub-region.

Modeling of Carbon Prices from RGGI

Compared to counterfactual with no carbon price

- Generation & Emissions
 - **Decrease** in carbon-price sub-region
 - **Increase** in rest of RTO
 - Net RTO impact varies based on sub-region assumptions
- Energy Prices
 - On average, LMPs **increase** in both sub-regions as the carbon price increases

Impacts of Border Adjustments

Compared to no border adjustment

- Generation & Emissions
 - **Increase** in carbon-price sub-region
 - **Decrease** in rest of RTO
 - Net RTO impact varies based on sub-region assumptions
- Energy Prices
 - On average, as the carbon price increases, a two-way border adjustment results in greater price **decreases** than a one-way border adjustment.

Review of Context and Study Assumptions

Part 1a: Impacts of a RGGI Carbon Price in the PJM Energy Market; Addition of VA to carbon-price sub-region

Part 2a: Impacts of Potential Border Adjustments for Leakage Mitigation; Addition of VA to carbon-price sub-region

Part 1b: Impacts of a RGGI Carbon Price in the PJM Energy Market; Addition of VA & PA to carbon-price sub-region

Part 2b: Impacts of Potential Border Adjustments for Leakage Mitigation; Addition of VA & PA to carbon-price sub-region

- **Leakage** - any shift in production and related emissions, from a regulated jurisdiction to a less-stringently regulated jurisdiction, due to differing compliance costs.
- In the context of the Regional Greenhouse Gas Initiative (RGGI), “Emissions leakage is the concept that there could be a shift of electricity generation from capped sources subject to RGGI to higher-emitting sources not subject to RGGI.” [1]
- Concerns raised by stakeholders in the CPSTF Opportunity Statement: “Without addressing leakage, rising emissions can eliminate the environmental benefits that carbon pricing policies are intended to produce. Similarly, leakage can also harm consumers in areas that have not adopted carbon pricing as more expensive resources push market clearing prices higher.” [2]

Note: Some studies consider emissions from power and non-power sectors, and emissions reduction goals when estimating leakage impacts. PJM study is focused on power sector emissions from simulation of the wholesale electricity market.

[1] Final Report of the RGGI Emissions Leakage Multi-State Staff Working Group to the RGGI Agency Heads. *Potential Emissions Leakage and the Regional Greenhouse Gas Initiative (RGGI)*. 2008.

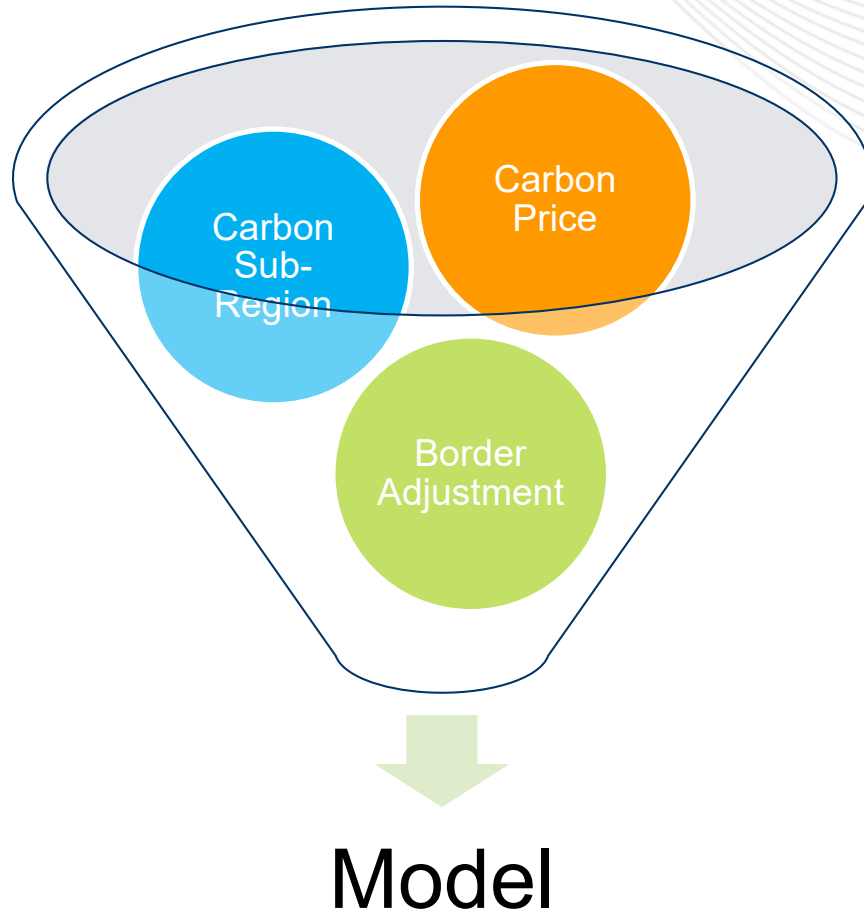
https://mde.maryland.gov/programs/Air/ClimateChange/RGGI/Documents/Leakage_Report_Final_3-08.pdf

[2] CPSTF Opportunity Statement, <https://www.pjm.com/-/media/committees-groups/task-forces/cpstf/postings/problem-statement.ashx?la=en>

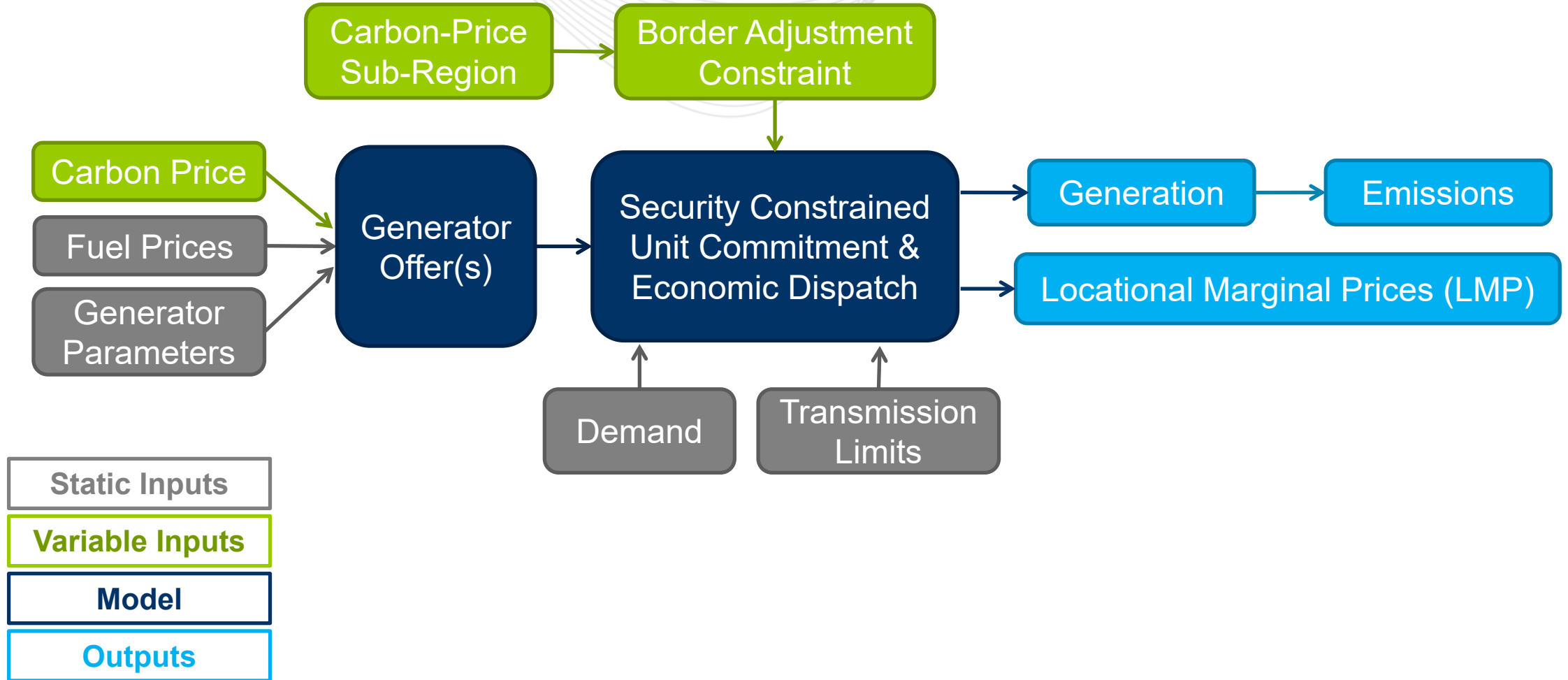
There are multiple approaches to leakage mitigation:

- *In study:* Border adjustment constraints within wholesale electricity market
 - One-way (transfers into carbon region)
 - Two-way (transfers into and out of carbon region)
- *Not in study:* State-specific approaches
 - Programs that reduce electricity demand
 - Load-based greenhouse gas compliance obligations
 - Allowance allocation
 - Support for increasing low / zero-emitting in-state generation

Setting up the model included using three key variable inputs



- Year Modeled: **2023** (most recent planning case from Regional Transmission Expansion Plan and Market Efficiency process)
- Variable inputs are used to look at energy market impacts of a carbon price and leakage mitigation approaches
- Utilized PLEXOS to simulate the commitment & dispatch of resources and the resulting market/emissions outcomes
- Potential future analysis: longer-term modeling to evaluate potential changes to resource mix due to a carbon price
 - Out of scope for this phase



\$0 /short ton of CO₂

- Applied in counterfactual case to quantify the impact of adding a carbon price on generation, emissions, and energy prices

\$6.87 /short ton of CO₂

- Low-end reference
- Trigger price for the RGGI Emissions Containment Reserve (ECR) in 2023

\$14.88 /short ton of CO₂

- High-end reference
- Trigger price for the RGGI Cost Containment Reserve (CCR) in 2023

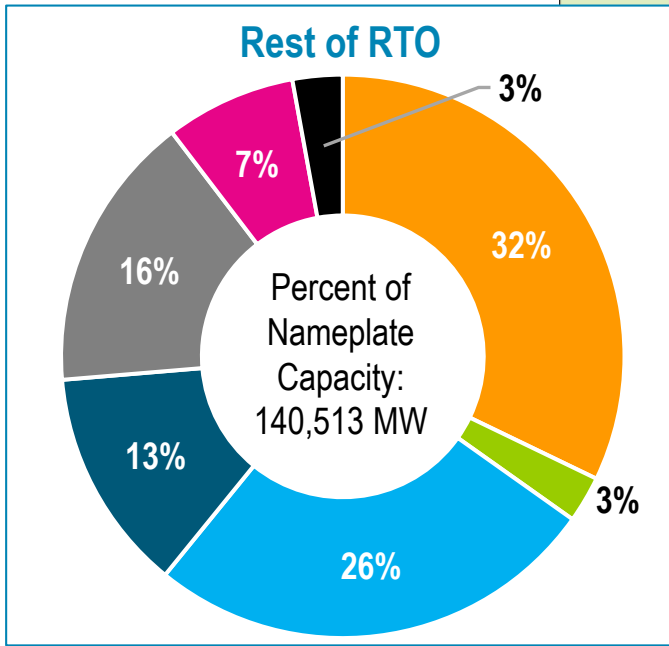
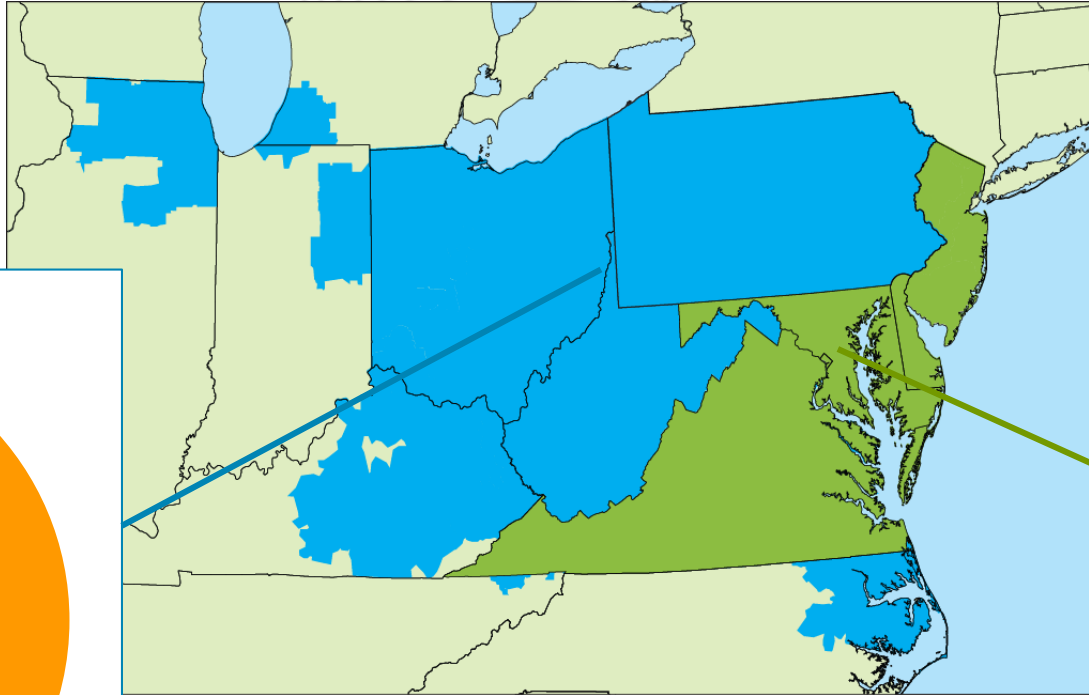


Internal and External resources to PJM are included in the optimization

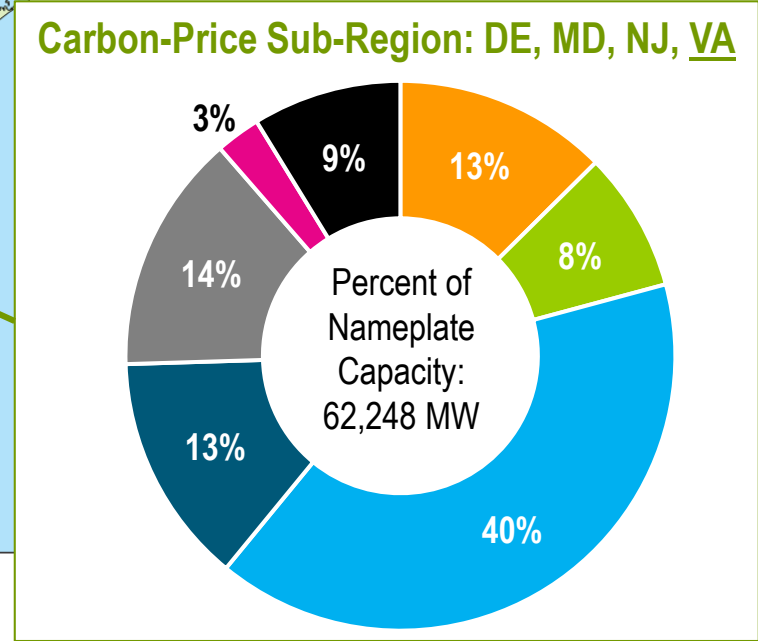
- Current set of results consider PJM states currently participating in RGGI (DE, MD, NJ), with the addition of VA and PA
- New York is modeled with a carbon price, as it is a RGGI state. Study results are focused on the PJM RTO.
- Resources both internal and external to PJM were included in the optimization.

Virginia is included in the Carbon Sub-Region

Results depend on the generation mix, and emissions intensities, of each sub-region.

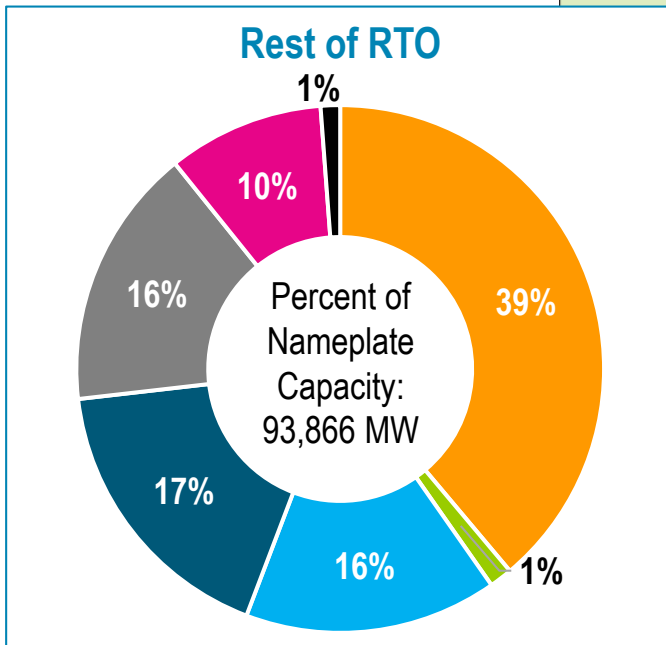
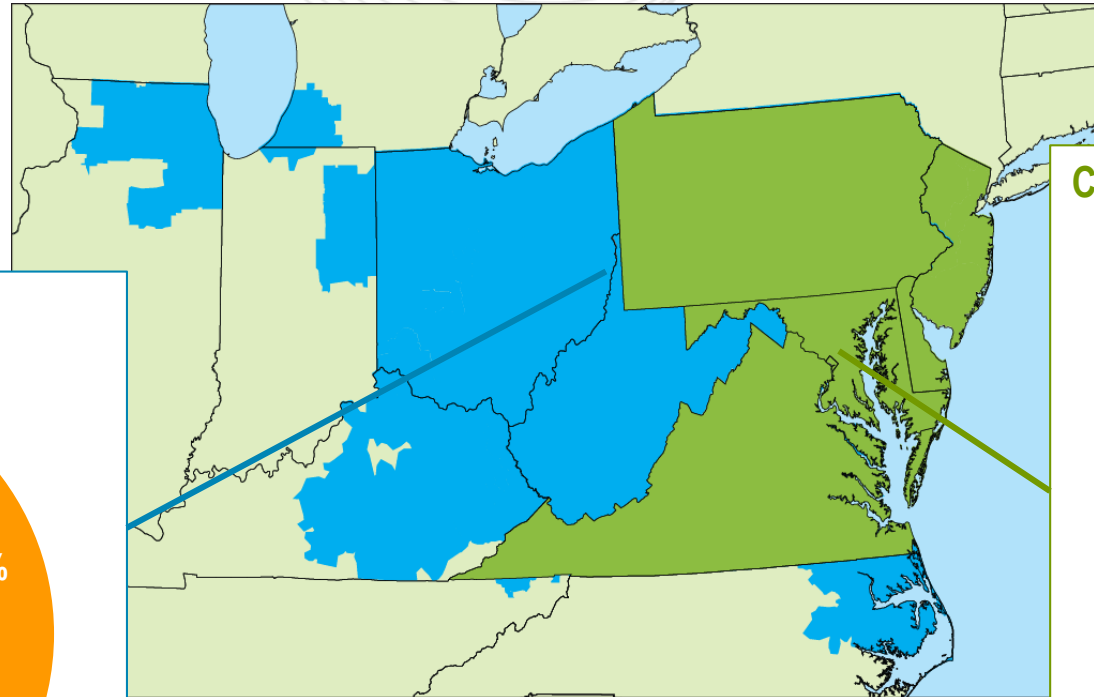


- Coal
- Natural Gas CT
- Hydro
- Other
- Natural Gas CC / Steam
- Nuclear
- Wind & Solar

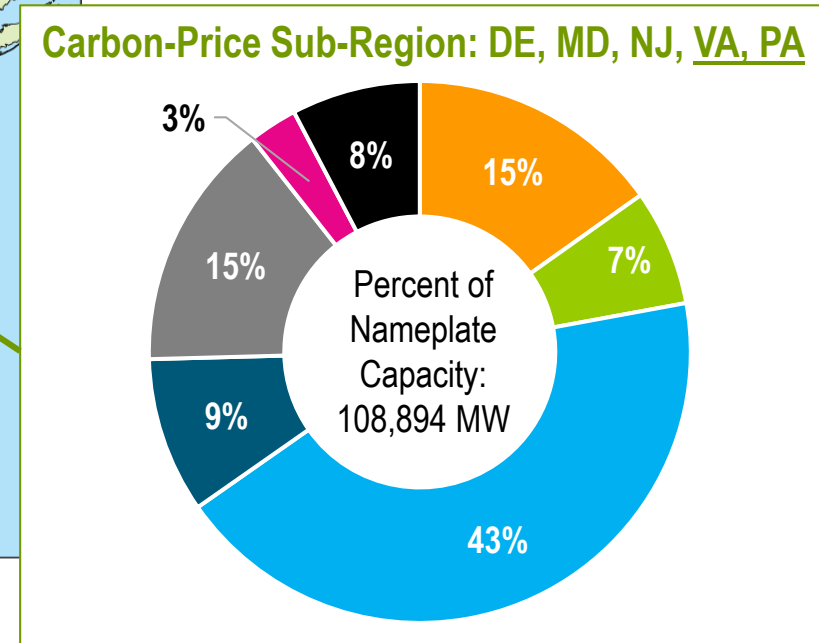


VA and PA are included in the Carbon Sub-Region

Results depend on the generation mix, and emissions intensities, of each sub-region.



- Coal
- Natural Gas CT
- Hydro
- Other
- Natural Gas CC / Steam
- Nuclear
- Wind & Solar



No Border Adjustment

- Determine baseline for economic and environmental leakage between regions

One-Way Border Adjustment

- Accounts for impacts of carbon price on transfers into the carbon-pricing region

Two-Way Border Adjustment

- Accounts for impacts of carbon price on transfers into carbon-pricing region and transfers from the carbon-pricing region

- Each state will continue to collect RGGI revenue from each RGGI Regulated Source located in its state as it does today.
- These financial transactions take place **outside** of the market and the grid operator's settlement process.

- The analysis will include the value of the carbon residual funds resulting from **border adjustments**. States, not PJM, will determine how these funds are allocated, **if any**.
 - **Surplus** possible when there are net transfers into the carbon-pricing region.
 - **Deficit** possible when there are net transfers from the carbon-pricing region.
- Based on the states that make up the carbon-price sub-region, there may not be any carbon residual funds.

Review of Context and Study Assumptions

Part 1a: Impacts of a RGGI Carbon Price in the PJM Energy Market; Addition of VA to carbon-price sub-region

Part 2a: Impacts of Potential Border Adjustments for Leakage Mitigation; Addition of VA to carbon-price sub-region

Part 1b: Impacts of a RGGI Carbon Price in the PJM Energy Market; Addition of VA & PA to carbon-price sub-region

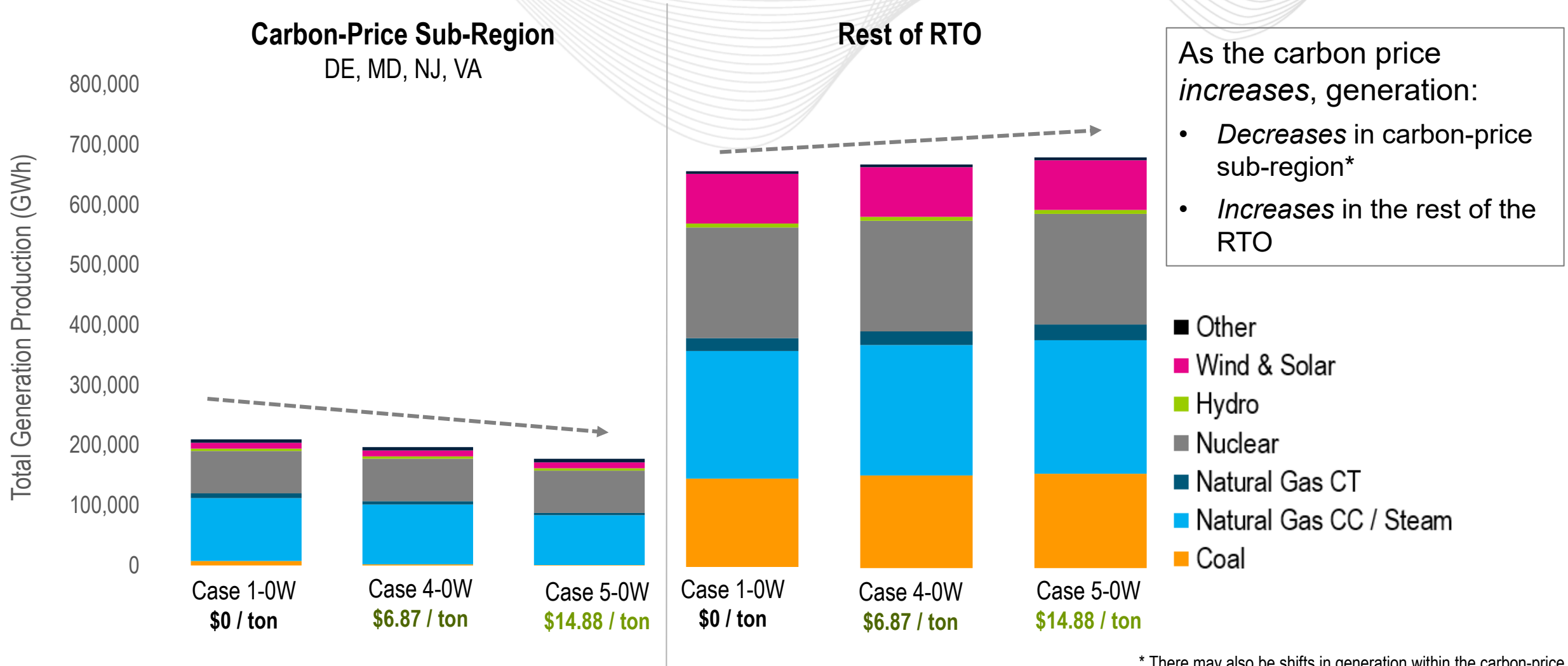
Part 2b: Impacts of Potential Border Adjustments for Leakage Mitigation; Addition of VA & PA to carbon-price sub-region

- Scenarios with RGGI price at \$6.87/short ton and \$14.88/short ton compared to a counterfactual scenario with RGGI price at \$0/short ton (“No RGGI”) to quantify differences in:
 - Generation
 - Emissions
 - Prices
- The year 2023 was simulated for the following cases:

Case	RGGI Price	Border Adjustment
Case 1-0W	\$0/short ton (i.e. “No RGGI Price”)	None
Case 4-0W	\$6.87/short ton	None
Case 5-0W	\$14.88/short ton	None

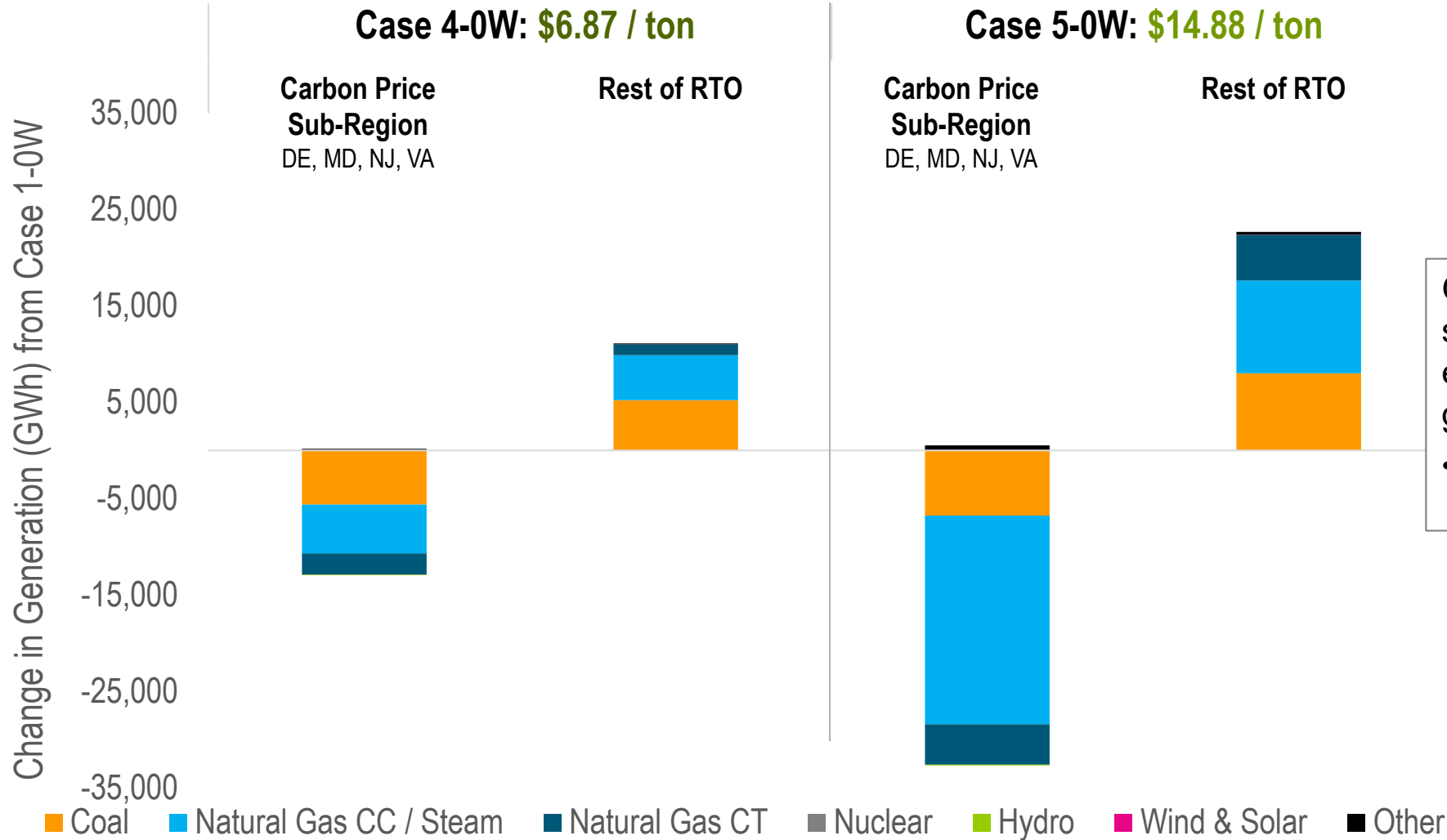
- Results are broken out by the following regions:
 - Carbon-Price Sub-Region – includes DE, MD, NJ **and VA**
 - Rest of RTO – all other states in PJM

2023 Generation Production by Sub-Region



* There may also be shifts in generation within the carbon-price sub-region, as the carbon price is only applied to RGGI generators.

2023 Shifts in Generation Production from Case 1-0W (\$0 / ton CO₂) by Sub-Region

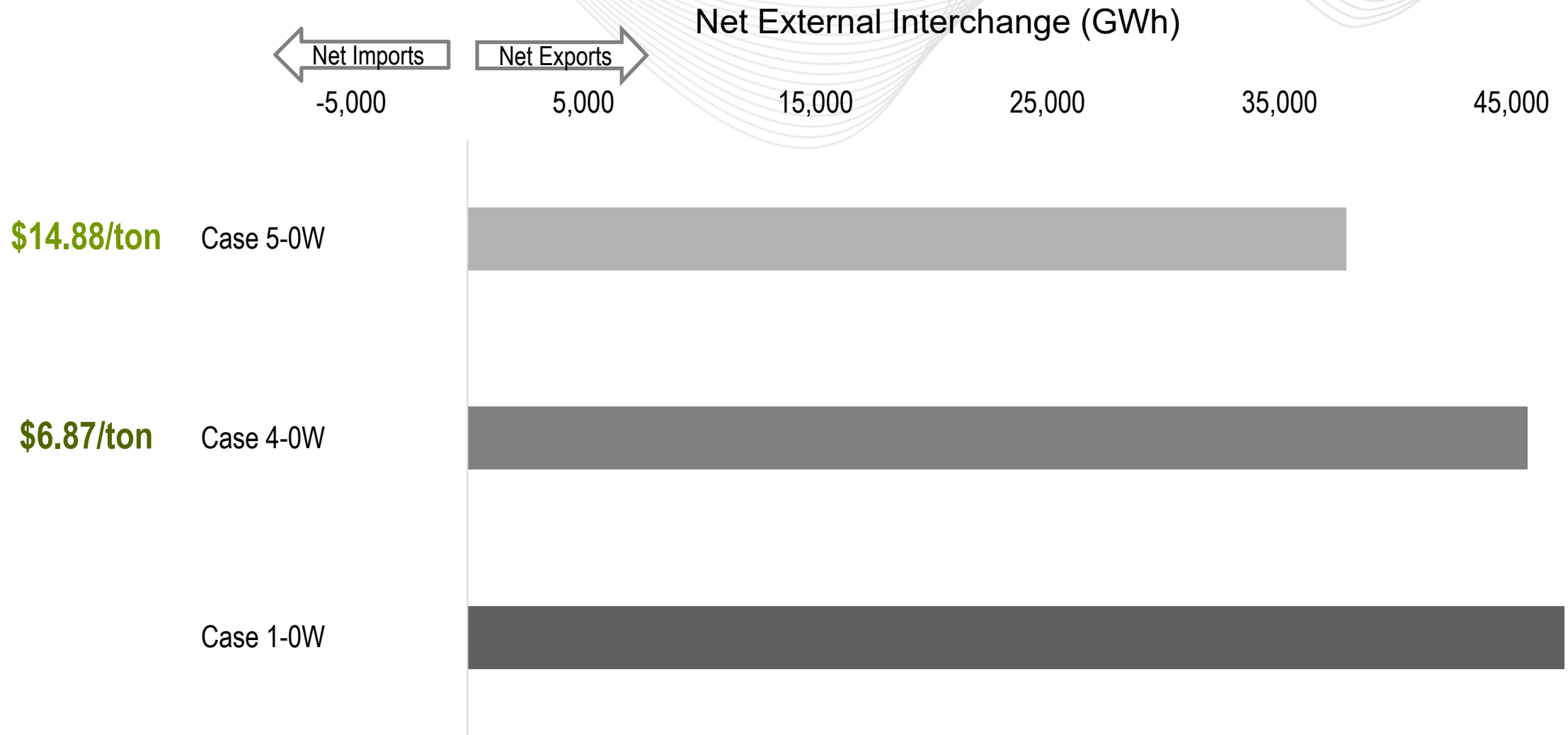


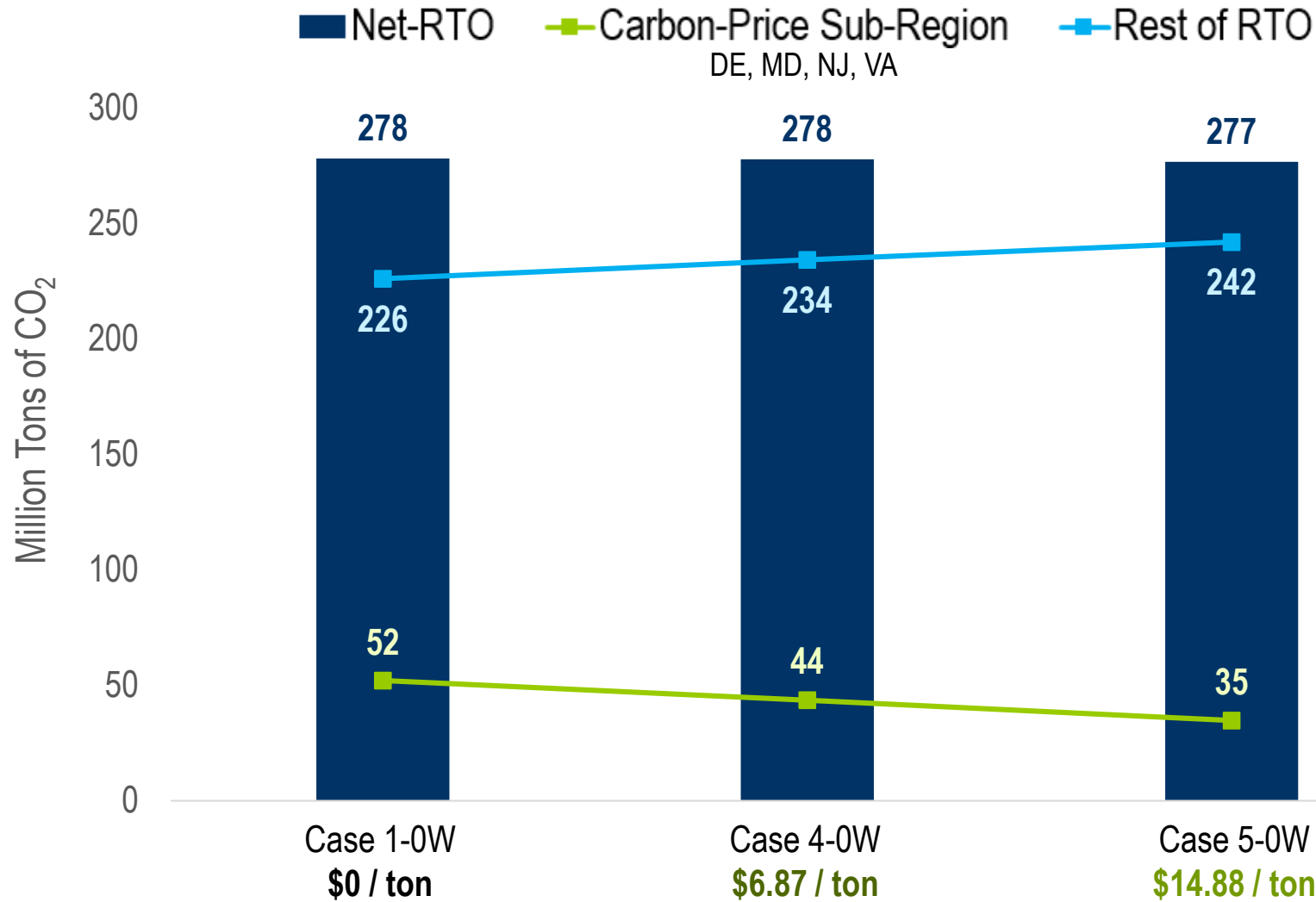
Generation displaced in carbon-price sub-region is relatively equivalent in emissions intensity to the increased generation in rest of RTO.

- Driven by generation mixes in each sub-region.



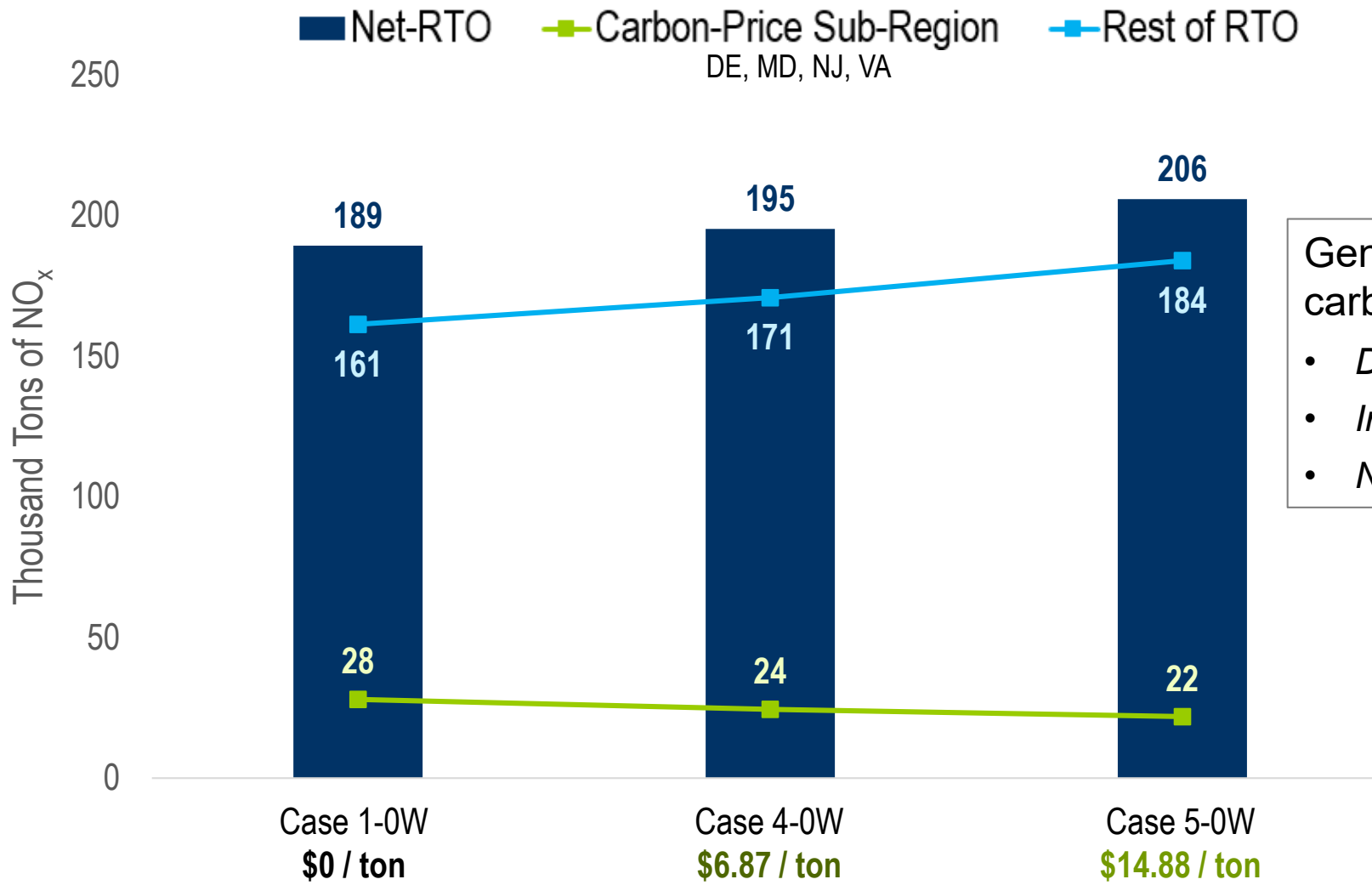
Interchange between PJM and External Regions





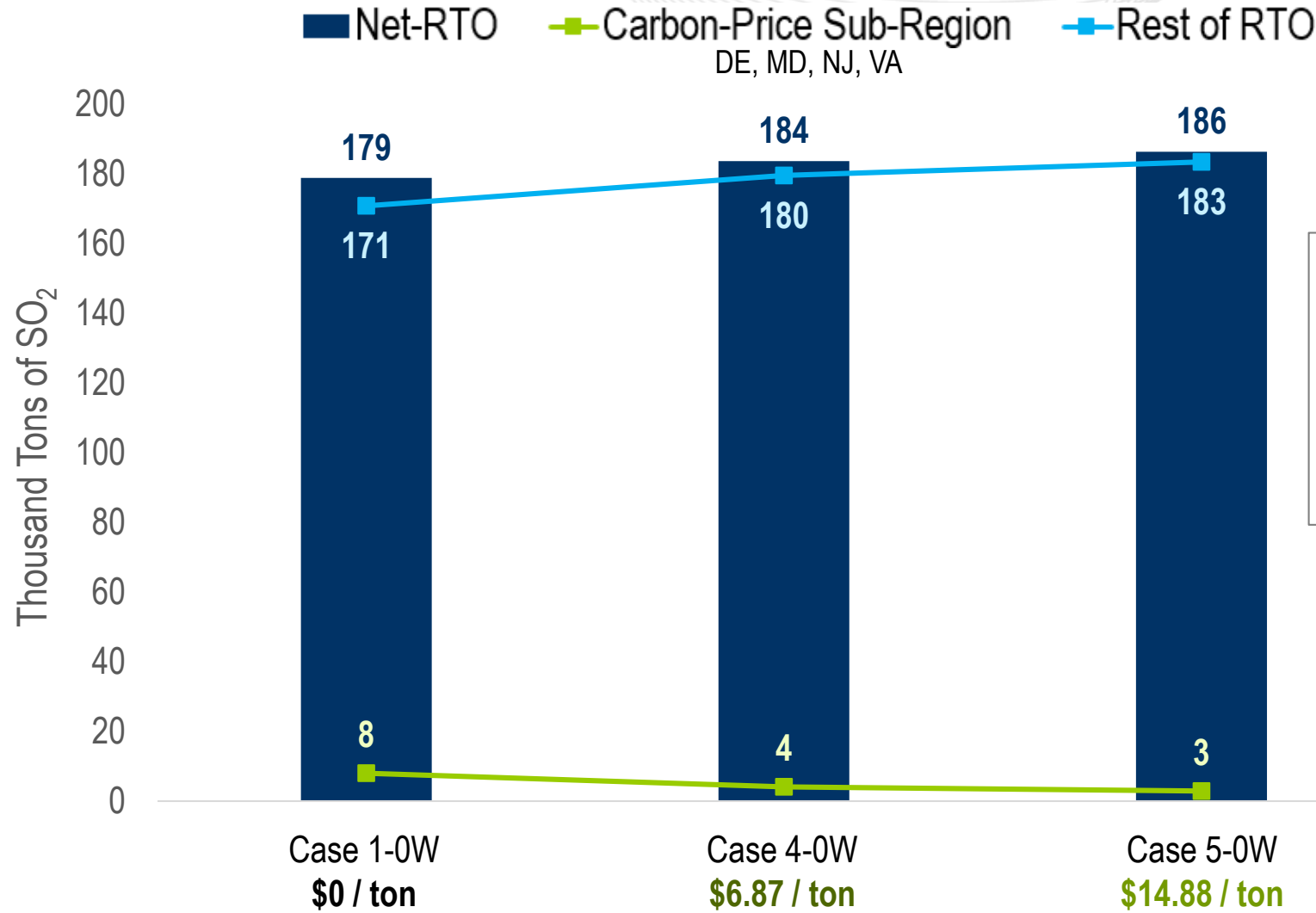
Generation shift from increasing carbon price results in CO₂:

- *Decrease* in carbon-price sub-region
- *Increase* in rest of RTO (no carbon price)
- *Net decrease* across the RTO



Generation shift from increasing carbon price results in CO₂:

- *Decrease* in carbon-price sub-region
- *Increase* in rest of RTO
- *Net increase* across the RTO

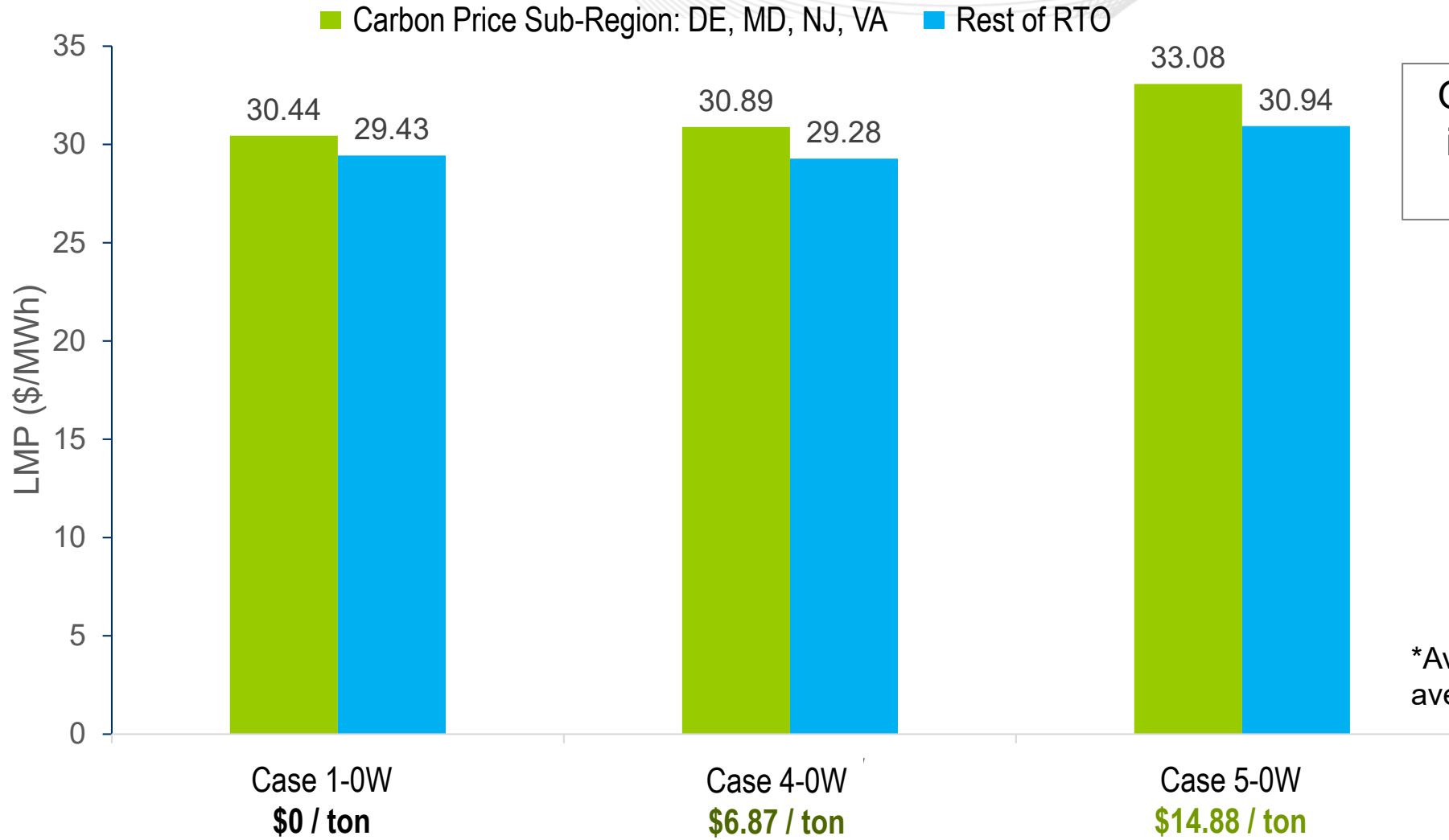


Generation shift from increasing carbon price results in CO₂:

- *Decrease* in carbon-price sub-region
- *Increase* in rest of RTO (no carbon price)
- *Net increase* across the RTO



2023 PJM Average Yearly LMPs* by Sub-Region & Carbon Price

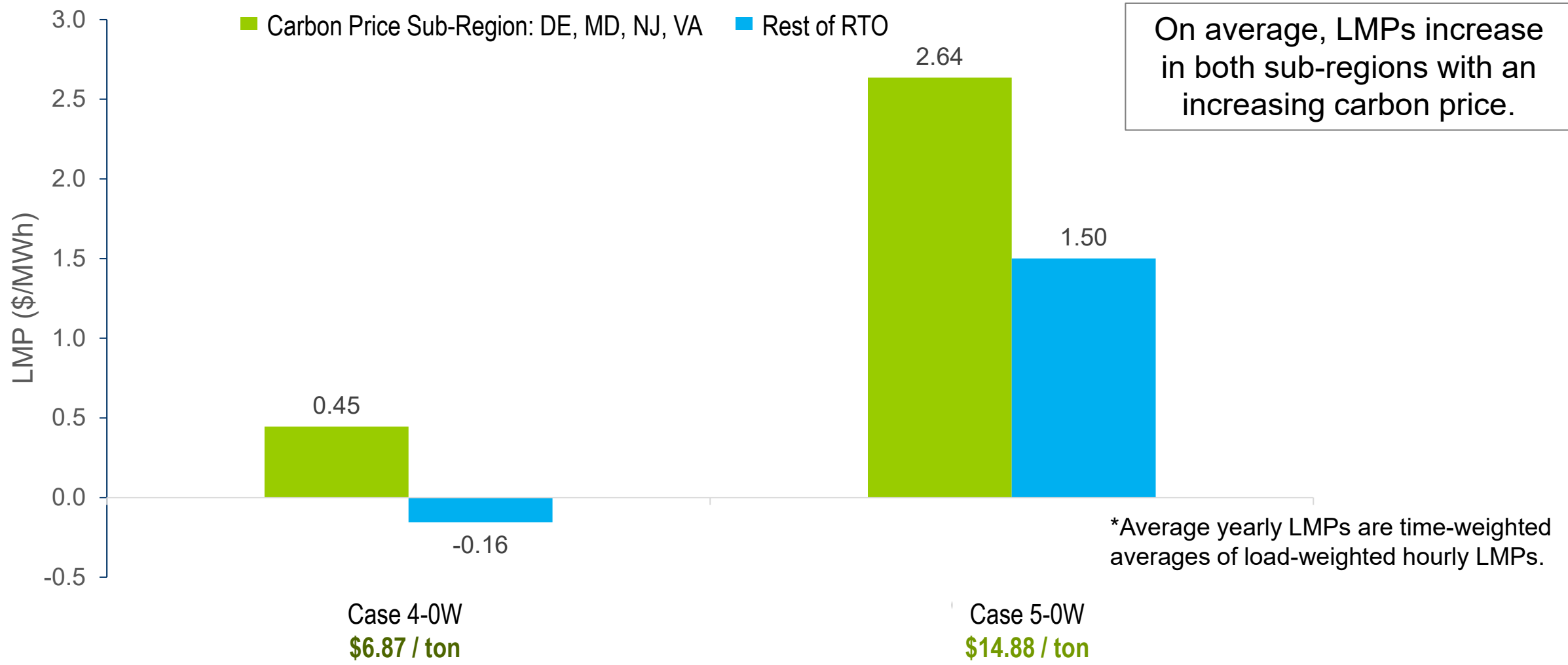


On average, LMPs increase in both sub-regions with an increasing carbon price.

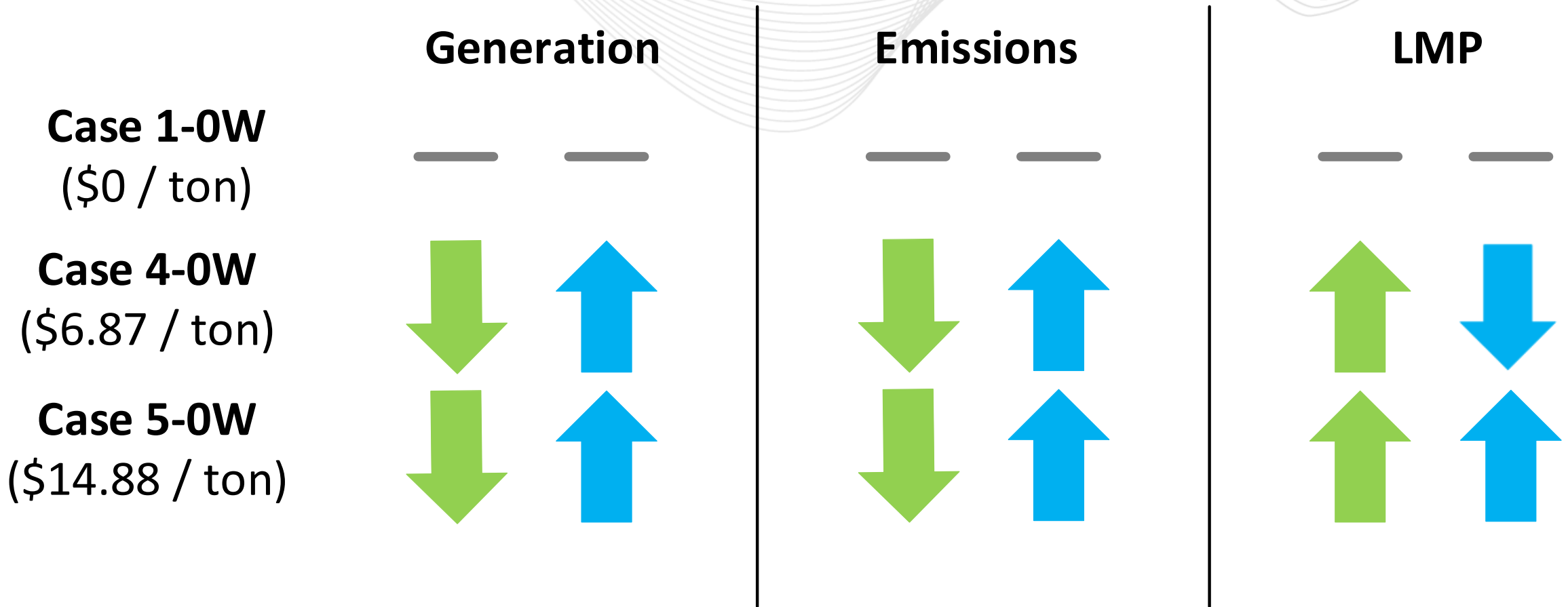
*Average yearly LMPs are time-weighted averages of load-weighted hourly LMPs.



2023 Difference in Average Yearly LMPs* from Case 1-0W by Sub-Region & Carbon Price



Part 1a: Impacts Associated with a RGGI Carbon Price in the PJM Energy Market



■ Carbon Price Sub-Region: DE, MD, NJ, VA
 ■ Rest of RTO

- **Generation:**

- Compared to the no carbon price scenario, the carbon price scenarios result in shifts in generation production from the Carbon-Price Sub-Region to the Rest of RTO.
- The generation displaced in the Carbon-Price Sub-Region has relatively equivalent emissions intensity compared to the increased generation in the Rest of RTO. This is driven by the generation mixes between of each sub-region.

- **Emissions:**

- The shift in generation production results in a decrease in emissions in the Carbon-Price Sub-Region and an increase in emissions in the Rest of RTO. This resulted in a net decrease in CO₂ emissions and a net increase in NO_x and SO₂ emissions across the RTO.

- **Energy Prices:**

- Compared to the scenario with no carbon price, on average, LMPs increase in both sub-regions as the carbon price increases.

Review of Context, Objectives, and Study Assumptions

Part 1a: Impacts of a RGGI Carbon Price in the PJM Energy Market; Addition of VA to carbon-price sub-region

Part 2a: Impacts of Potential Border Adjustments for Leakage Mitigation; Addition of VA to carbon-price sub-region

Part 1b: Impacts of a RGGI Carbon Price in the PJM Energy Market; Addition of VA & PA to carbon-price sub-region

Part 2b: Impacts of Potential Border Adjustments for Leakage Mitigation; Addition of VA & PA to carbon-price sub-region

- Two leakage mitigation mechanisms were studied and were compared against the case with no leakage mitigation
 - 1) No Border Adjustment (no leakage mitigation)
 - 2) One-Way Border Adjustment
 - 3) Two-Way Border Adjustment
- Each leakage mitigation mechanism was studied using the RGGI ECR price of \$6.87/short ton and the RGGI CCR price of \$14.88/short ton.

- The year 2023 was simulated for the following cases for the carbon-price sub-region that included DE, MD, NJ and VA:

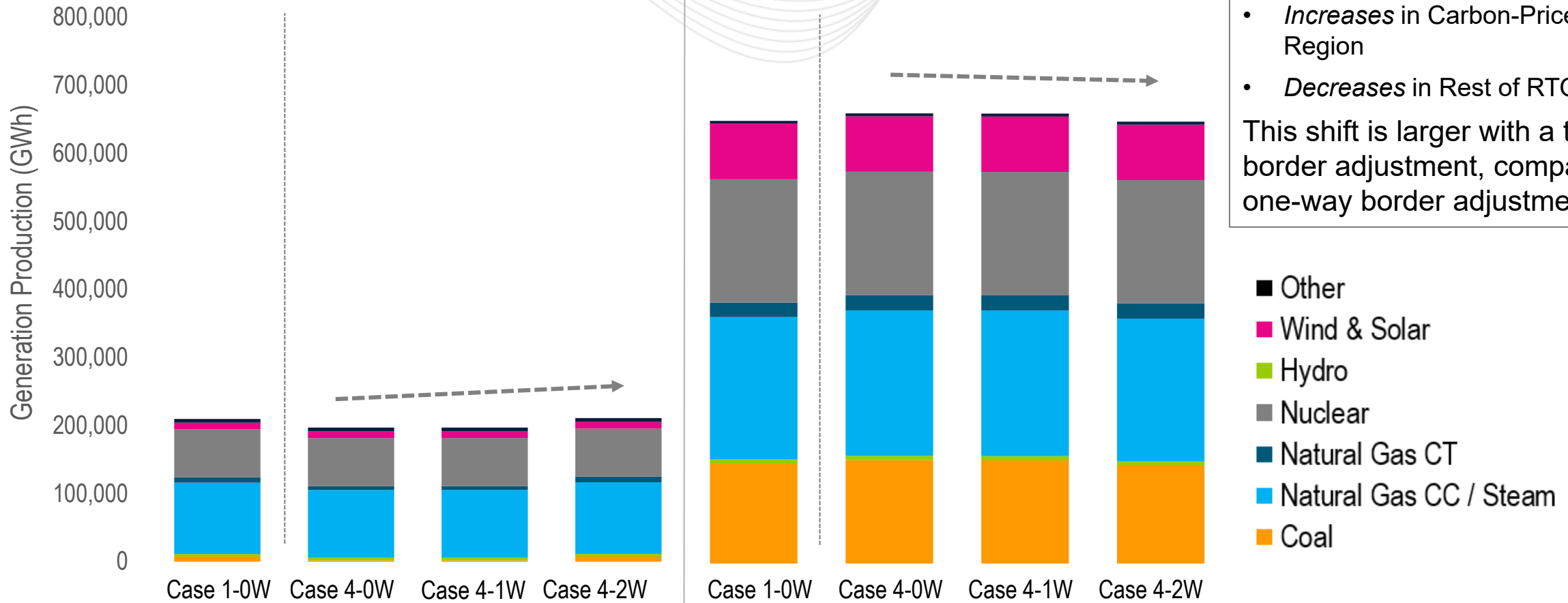
Case	RGGI Price	Border Adjustment
Case 4-0W	\$6.87/short ton	None
Case 4-1W	\$6.87/short ton	One-Way
Case 4-2W	\$6.87/short ton	Two-Way
Case 5-0W	\$14.88/short ton	None
Case 5-1W	\$14.88/short ton	One-Way
Case 5-2W	\$14.88/short ton	Two-Way

- The following metrics are compared for each simulation case:
 - Generation
 - Emissions
 - Prices
 - Carbon Revenue (Residual Funds)
- Results are broken out by the following regions:
 - Carbon-Price Sub-Region – includes **DE, MD, NJ and VA**
 - Rest of RTO – all other states in PJM

2023 Generation Production by Sub-Region: \$6.87 / ton CO₂

Carbon-Price Sub-Region (DE, MD, NJ, VA)

Rest of RTO



With the addition of a border adjustment, generation:

- *Increases* in Carbon-Price Sub-Region
- *Decreases* in Rest of RTO

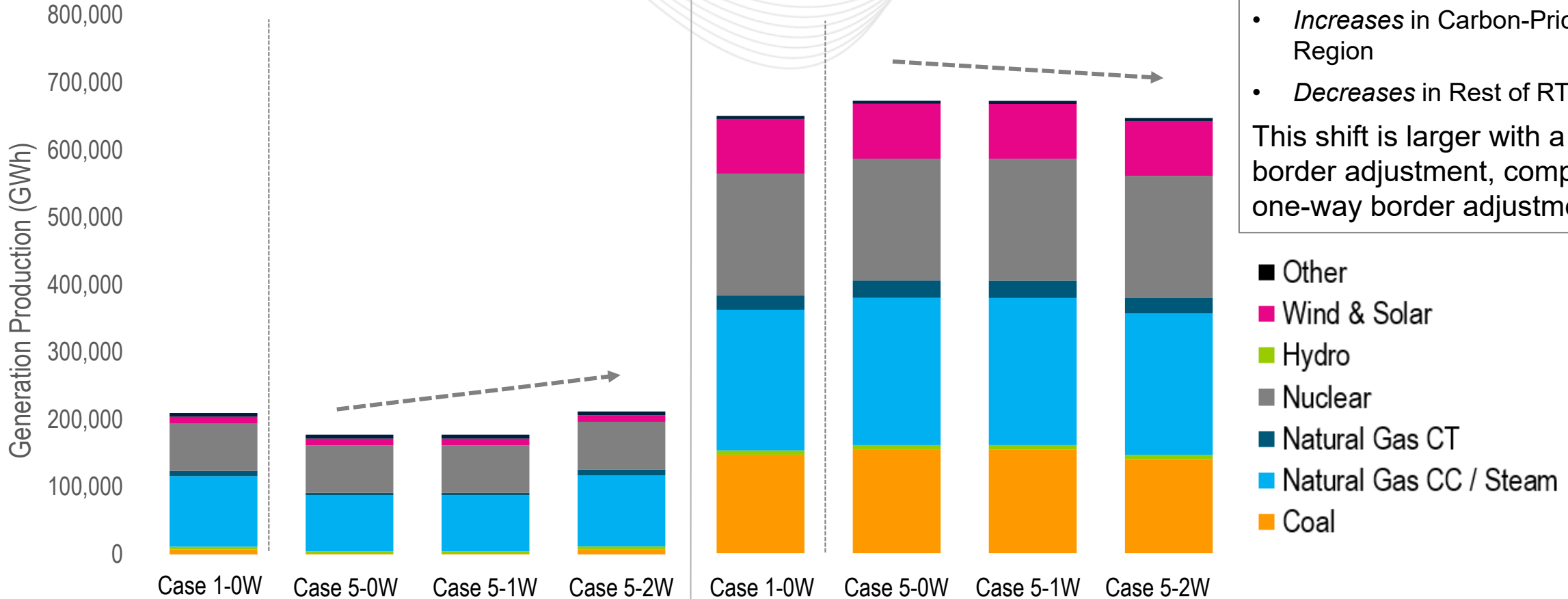
This shift is larger with a two-way border adjustment, compared to a one-way border adjustment.

- Other
- Wind & Solar
- Hydro
- Nuclear
- Natural Gas CT
- Natural Gas CC / Steam
- Coal

2023 Generation Production by Sub-Region: \$14.88 / ton CO₂

Carbon-Price Sub-Region (DE, MD, NJ, VA)

Rest of RTO



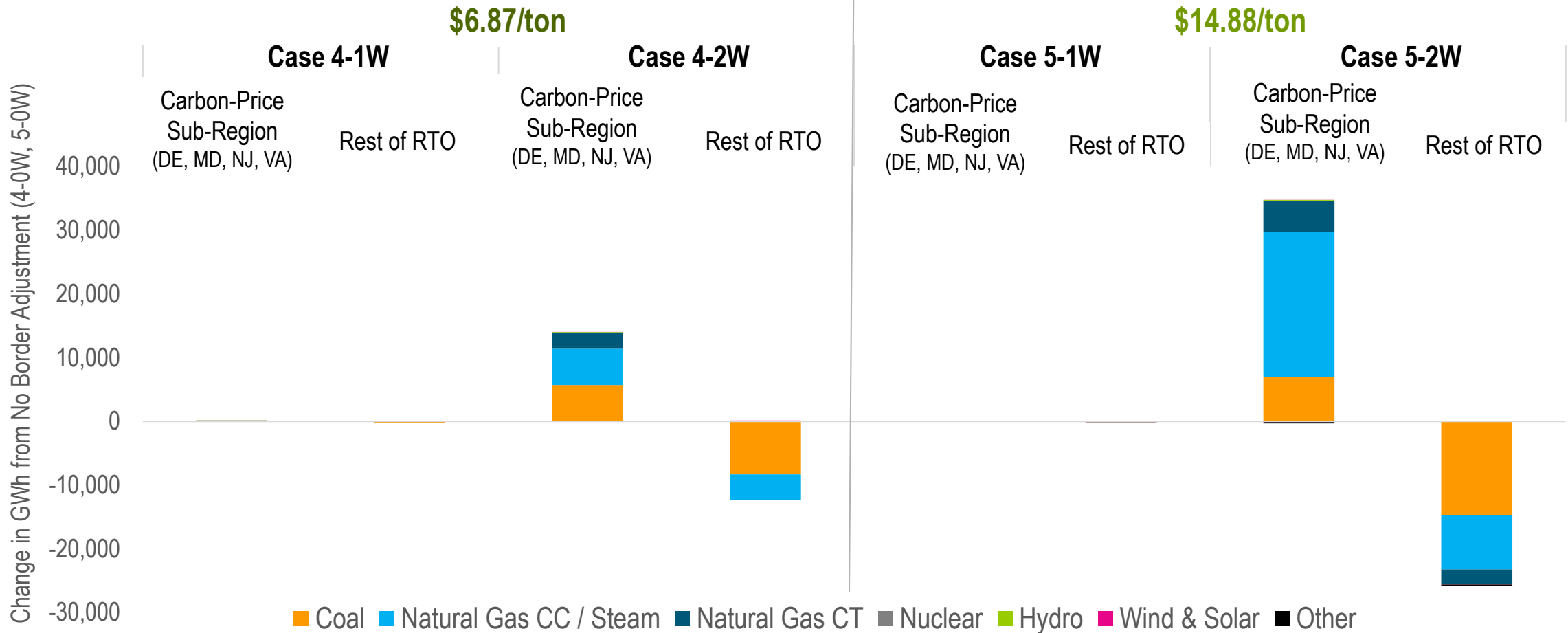
With the addition of a border adjustment, generation:

- *Increases* in Carbon-Price Sub-Region
- *Decreases* in Rest of RTO

This shift is larger with a two-way border adjustment, compared to a one-way border adjustment.

- Other
- Wind & Solar
- Hydro
- Nuclear
- Natural Gas CT
- Natural Gas CC / Steam
- Coal

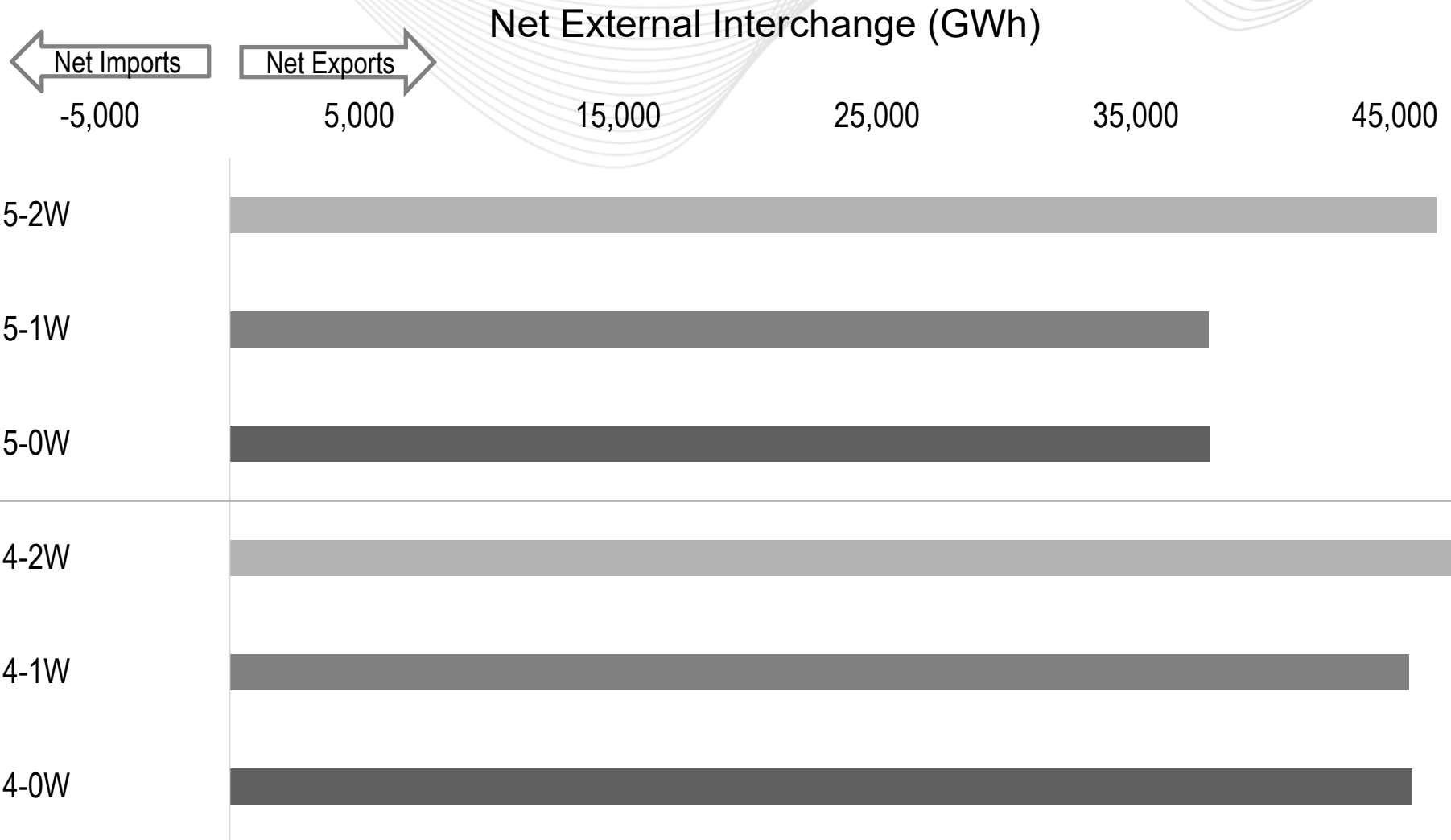
Shift in Generation Production by Sub-Region from adding Border Adjustment



Larger generation shift with a two-way border adjustment, compared to a one-way border adjustment. Increased generation in Carbon-Price Sub-Region is relatively lower-emitting than the displaced generation in rest of RTO.



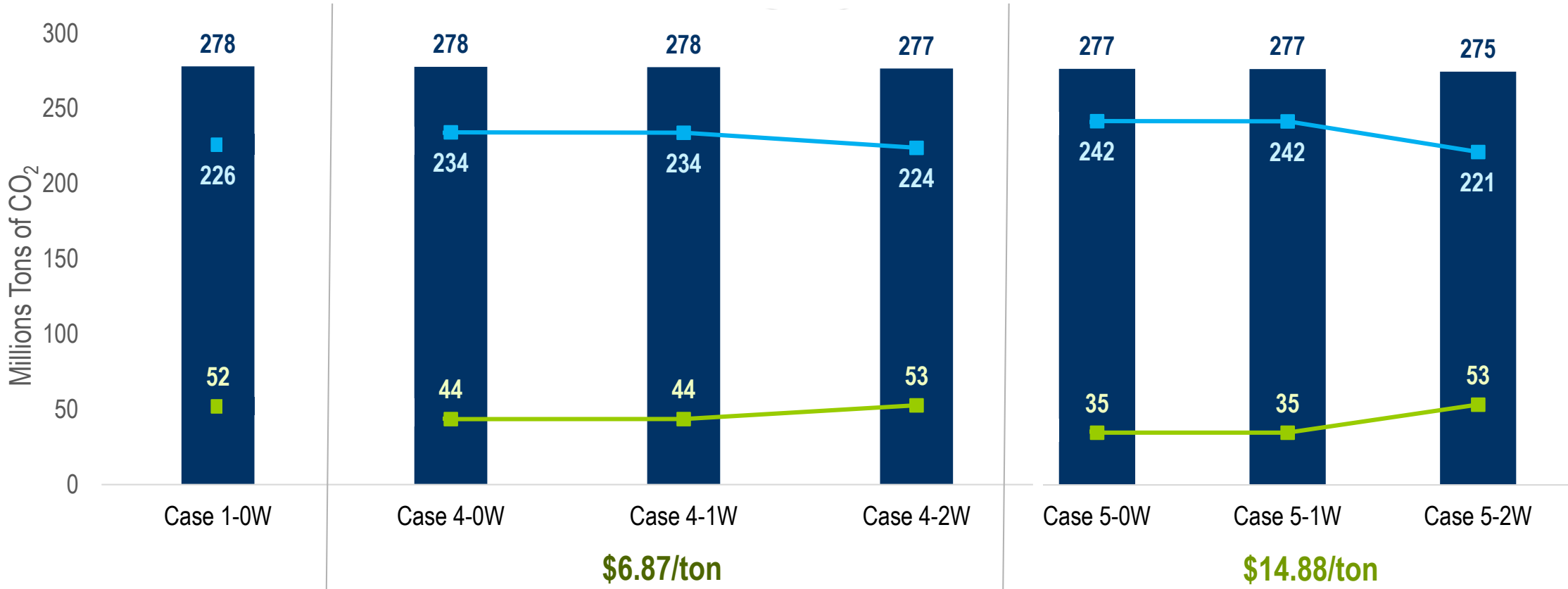
Interchange between PJM and External Regions



Impact of Border Adjustment on CO₂ Emissions

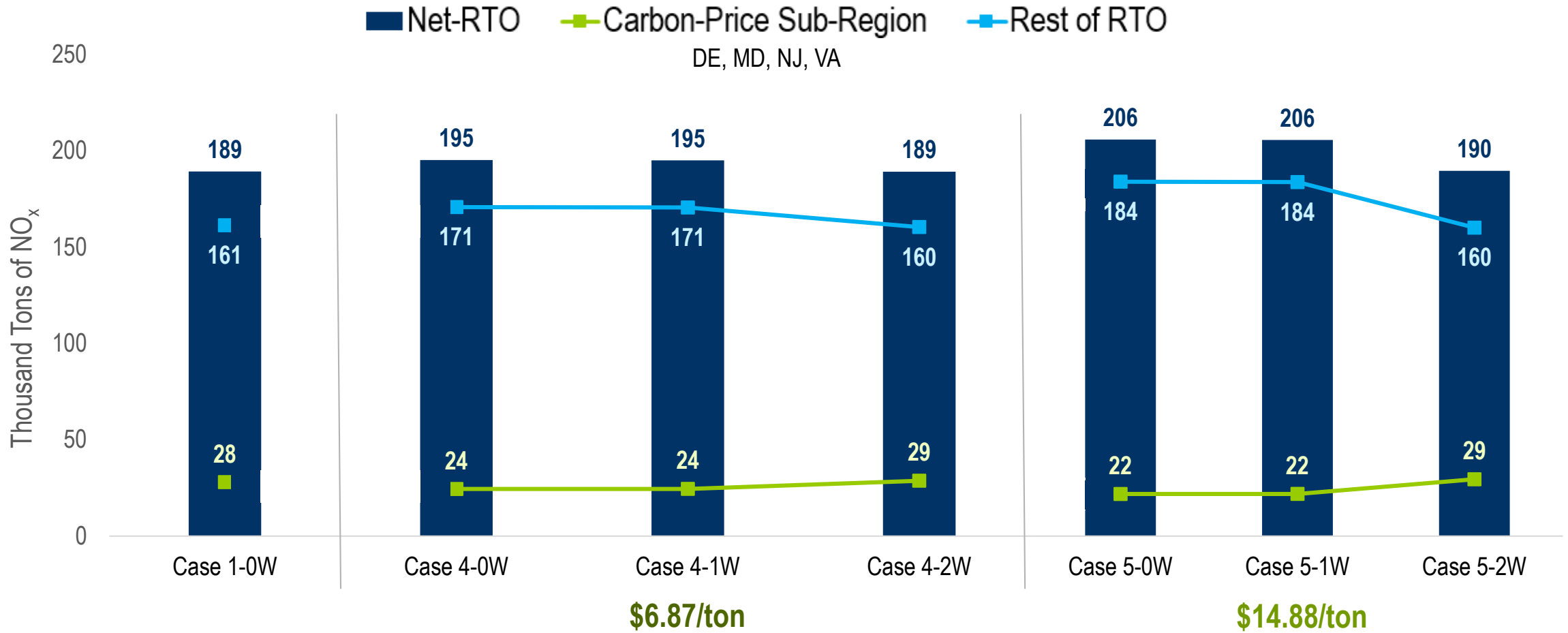
Generation shift from border adjustment results in emissions *increase* in Carbon-Price Sub-Region, *decrease* in Rest of RTO and *net decrease* across Net-RTO.

■ Net-RTO
 ■ Carbon-Price Sub-Region
 ■ Rest of RTO
 DE, MD, NJ, VA



Impact of Border Adjustment on NO_x Emissions

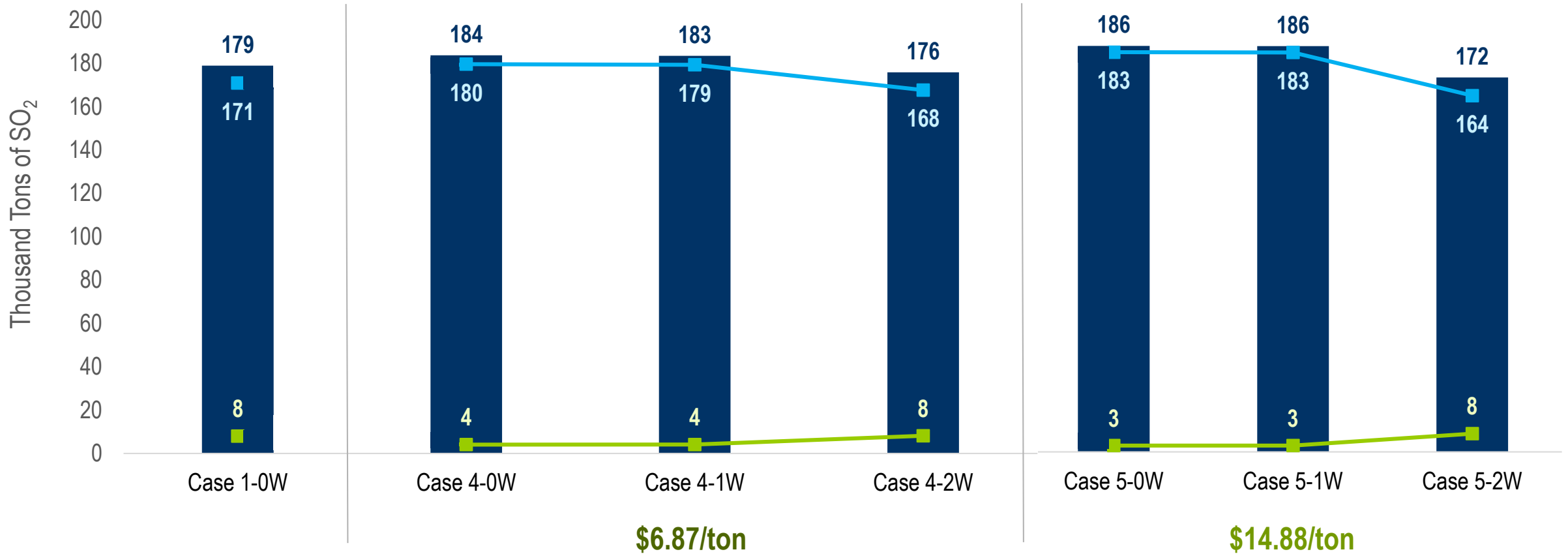
Generation shift from border adjustment results in emissions *increase* in Carbon-Price Sub-Region, *decrease* in Rest of RTO and *net decrease* across Net-RTO.



Impact of Border Adjustment on SO₂ Emissions

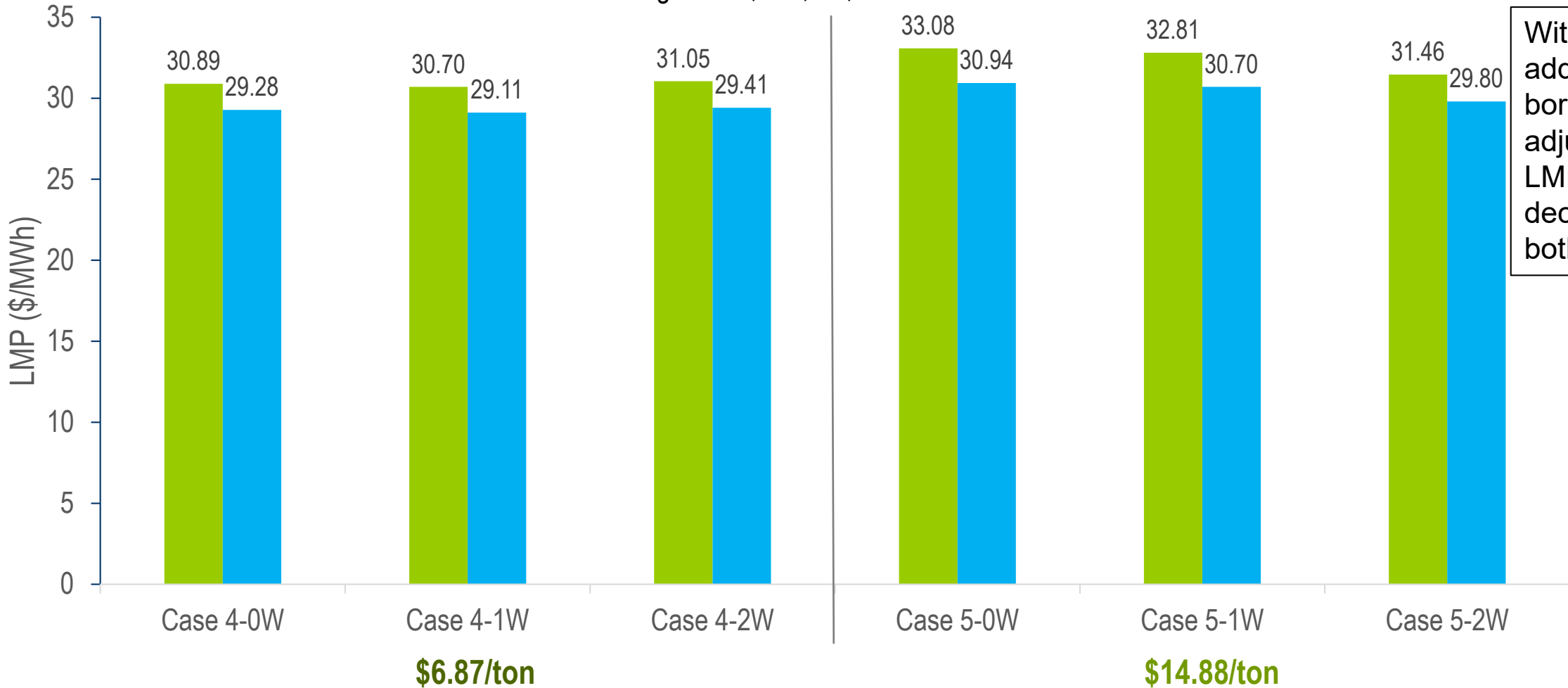
Generation shift from border adjustment results in emissions *increase* in Carbon-Price Sub-Region, *decrease* in Rest of RTO and *net decrease* across Net-RTO.

■ Net-RTO ■ Carbon-Price Sub-Region DE, MD, NJ, VA ■ Rest of RTO



2023 PJM Average Yearly LMPs* by Sub-Region

■ Carbon-Price Sub-Region: DE, MD, NJ, VA ■ Rest of RTO

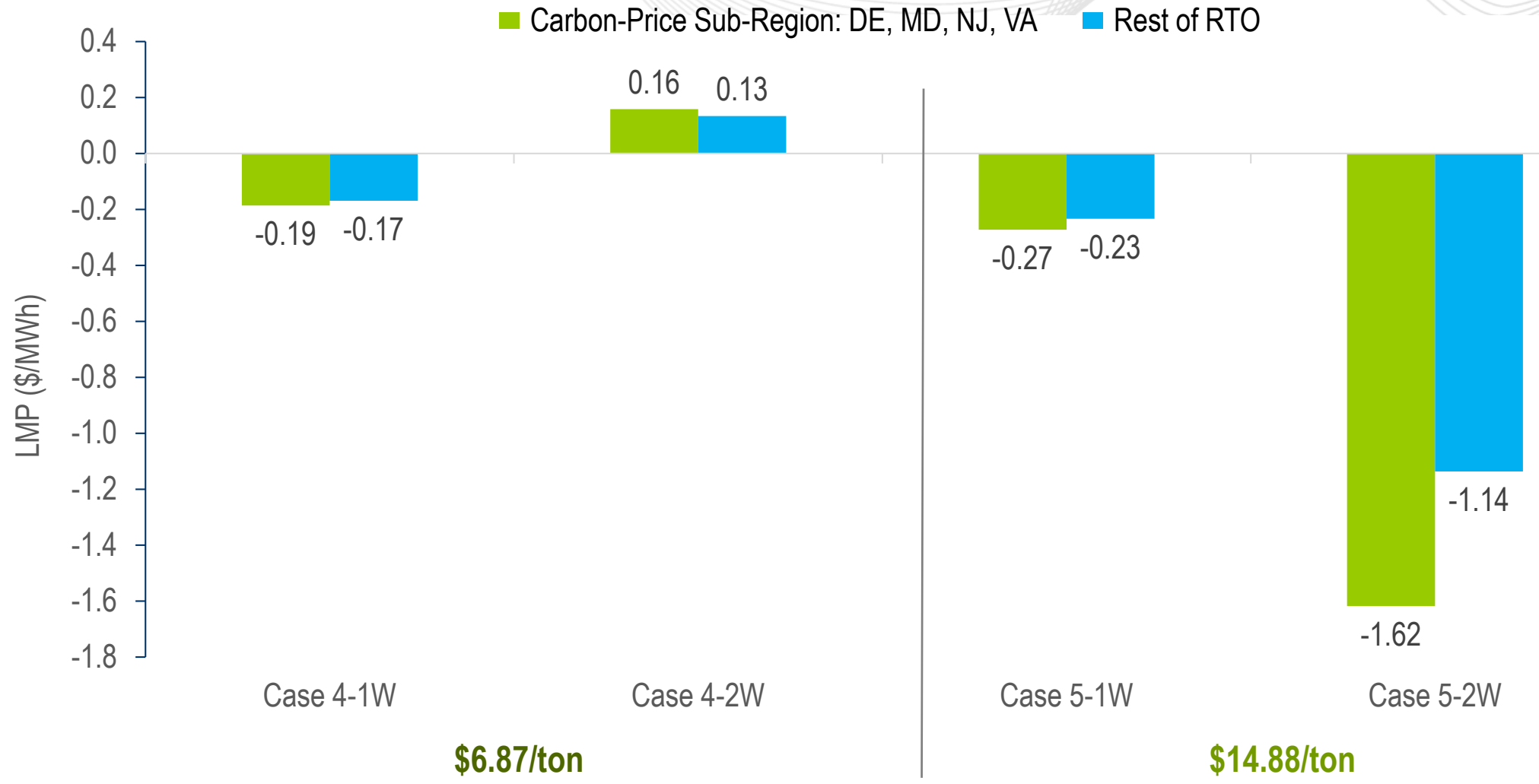


With the addition of a border adjustment, LMPs tend to decrease for both regions.

*Average yearly LMPs are time-weighted averages of load-weighted hourly LMPs.



2023 Difference in Average Yearly LMPs* from Case 0W by Sub-Region and RGGI Price



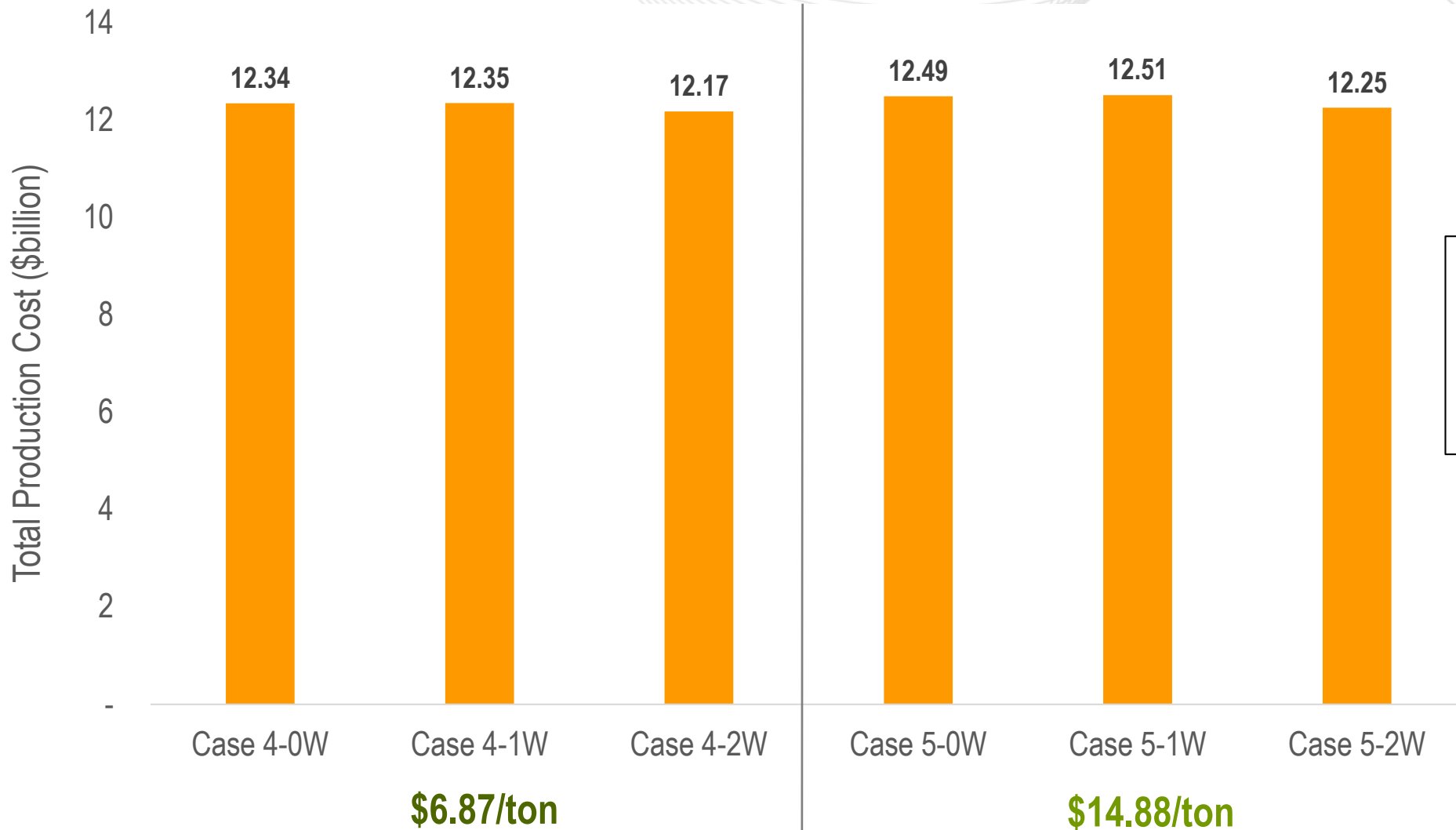
\$6.87/ton

\$14.88/ton

With the addition of a border adjustment, LMPs tend to decrease for both regions.

*Average yearly LMPs are time-weighted averages of load-weighted hourly LMPs.

Impact of Border Adjustments on 2023 RTO Total Production Cost



Total System Production Cost:

- *Increases* with a one-way border adjustment
- *Decreases* with a two-way border adjustment

- As previously noted, compared to scenarios with no leakage mitigation, the border adjustment scenarios result in shifts in generation production from the Rest of RTO to the Carbon-Price Sub-Region.
- This could be assumed to increase the funds from CO₂ allowance sales that states would collect if the CO₂ compliance obligation continues to be placed on the emitting generators in their states.
- However, it is possible in the **two-way** border adjustment case, that generators will not receive enough revenue through the market to cover their RGGI compliance obligations (which are paid outside the market) and generation costs.

- In all simulation cases, there are no carbon residual funds at any time.
- This is because the carbon component of the LMP is \$0/MWh at all times in all cases.
- In other words, the carbon cost of the marginal unit being transferred from the Rest of RTO Sub-Region to the Carbon-Price Sub-Region is zero in all the simulation cases.

Part 2a: Impacts of Potential Border Adjustments for Leakage Mitigation

	Generation		Emissions		LMP	
Case 4-0W (\$6.87 / ton)	—	—	—	—	—	—
Case 4-1W (\$6.87 / ton)	↑	↓	↑	↓	↓	↓
Case 4-2W (\$6.87 / ton)	↑	↓	↑	↓	↑	↑
Case 5-0W (\$14.88 / ton)	—	—	—	—	—	—
Case 5-1W (\$14.88 / ton)	↑	↓	↑	↓	↓	↓
Case 5-2W (\$14.88 / ton)	↑	↓	↑	↓	↓	↓

■ Carbon Price Sub-Region: DE, MD, NJ, VA
 ■ Rest of RTO

- **Generation:**

- Compared to scenarios with no leakage mitigation, the border adjustment scenarios result in shifts in generation production from the Rest of RTO to the Carbon-Price Sub-Region.
- This generation shift increases as the price of carbon increases, and is greater with a two-way border adjustment, compared to a one-way border adjustment.
- The generation displaced in the Rest of RTO has a relatively higher emissions intensity than the increased generation in the Carbon-Price Sub-Region.

- **Emissions:**

- Use of a border adjustment mechanism resulted in an increase in emissions in the Carbon-Price Sub-Region, a decrease in emissions in the Rest of RTO, and a net decrease in total Net-RTO emissions.
- These shifts in emissions are greater with a two-way border adjustment, compared to a one-way border adjustment.
- The change in emissions is greater as the carbon price increases.

- **Energy Prices:**

- Use of a border adjustment mechanism may mitigate the impact of a carbon price on the LMP.
- Compared to scenarios with no leakage mitigation, on average, as the carbon price increases, a two-way border adjustment results in greater price decreases than a one-way border adjustment.

Review of Context, Objectives, and Study Assumptions

Part 1a: Impacts of a RGGI Carbon Price in the PJM Energy Market; Addition of VA to carbon-price sub-region

Part 2a: Impacts of Potential Border Adjustments for Leakage Mitigation; Addition of VA to carbon-price sub-region

Part 1b: Impacts of a RGGI Carbon Price in the PJM Energy Market; Addition of VA & PA to carbon-price sub-region

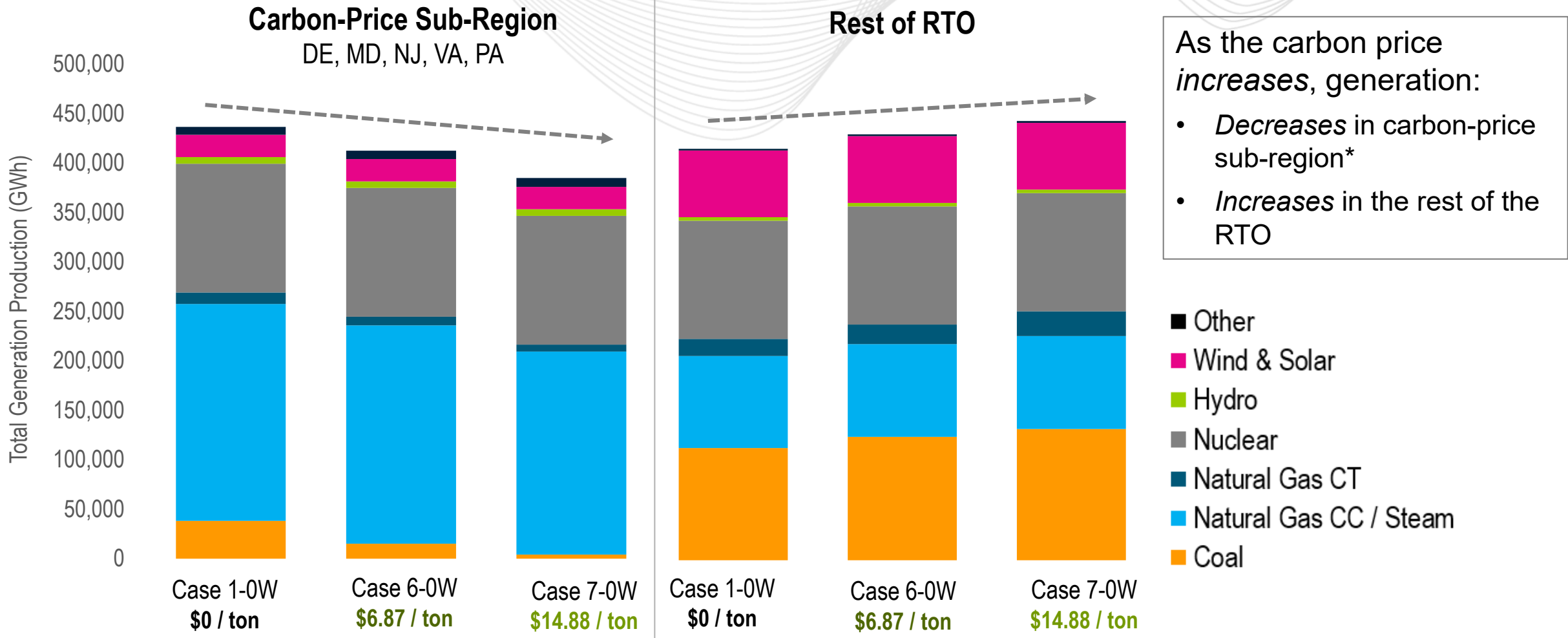
Part 2b: Impacts of Potential Border Adjustments for Leakage Mitigation; Addition of VA & PA to carbon-price sub-region

- Scenarios with RGGI price at \$6.87/short ton and \$14.88/short ton compared to a counterfactual scenario with RGGI price at \$0/short ton (“No RGGI”) to quantify differences in:
 - Generation
 - Emissions
 - Prices
- The year 2023 was simulated for the following cases:

Case	RGGI Price	Border Adjustment
Case 1-0W	\$0/short ton (i.e. “No RGGI Price”)	None
Case 6-0W	\$6.87/short ton	None
Case 7-0W	\$14.88/short ton	None

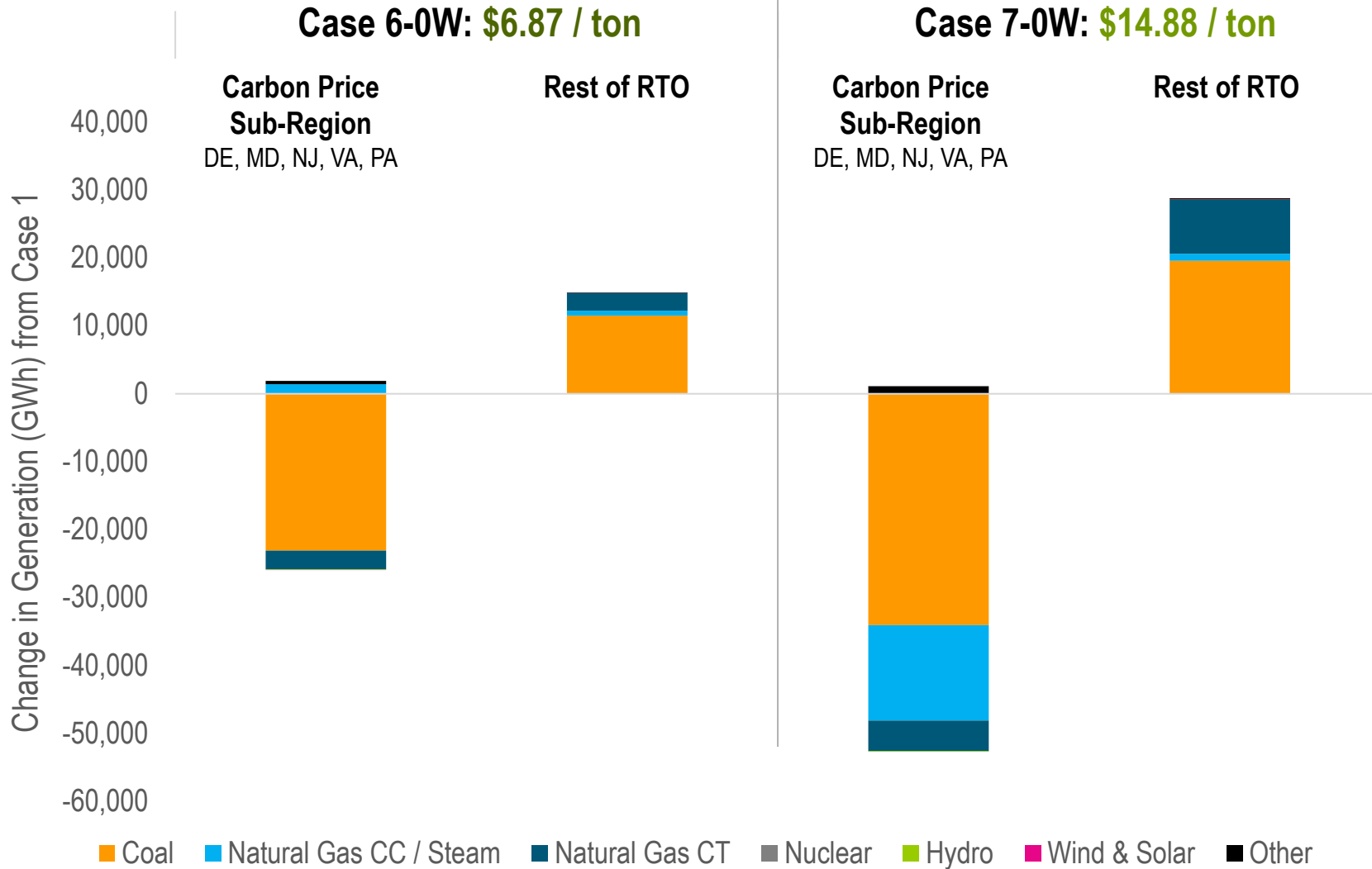
- Results are broken out by the following regions:
 - Carbon-Price Sub-Region – includes DE, MD, NJ, **VA and PA**
 - Rest of RTO – all other states in PJM

2023 Generation Production by Sub-Region



* There may also be shifts in generation within the carbon-price sub-region, as the carbon price is only applied to RGGI generators.

2023 Shifts in Generation Production from Case 1-0W (\$0 / ton CO₂) by Sub-Region

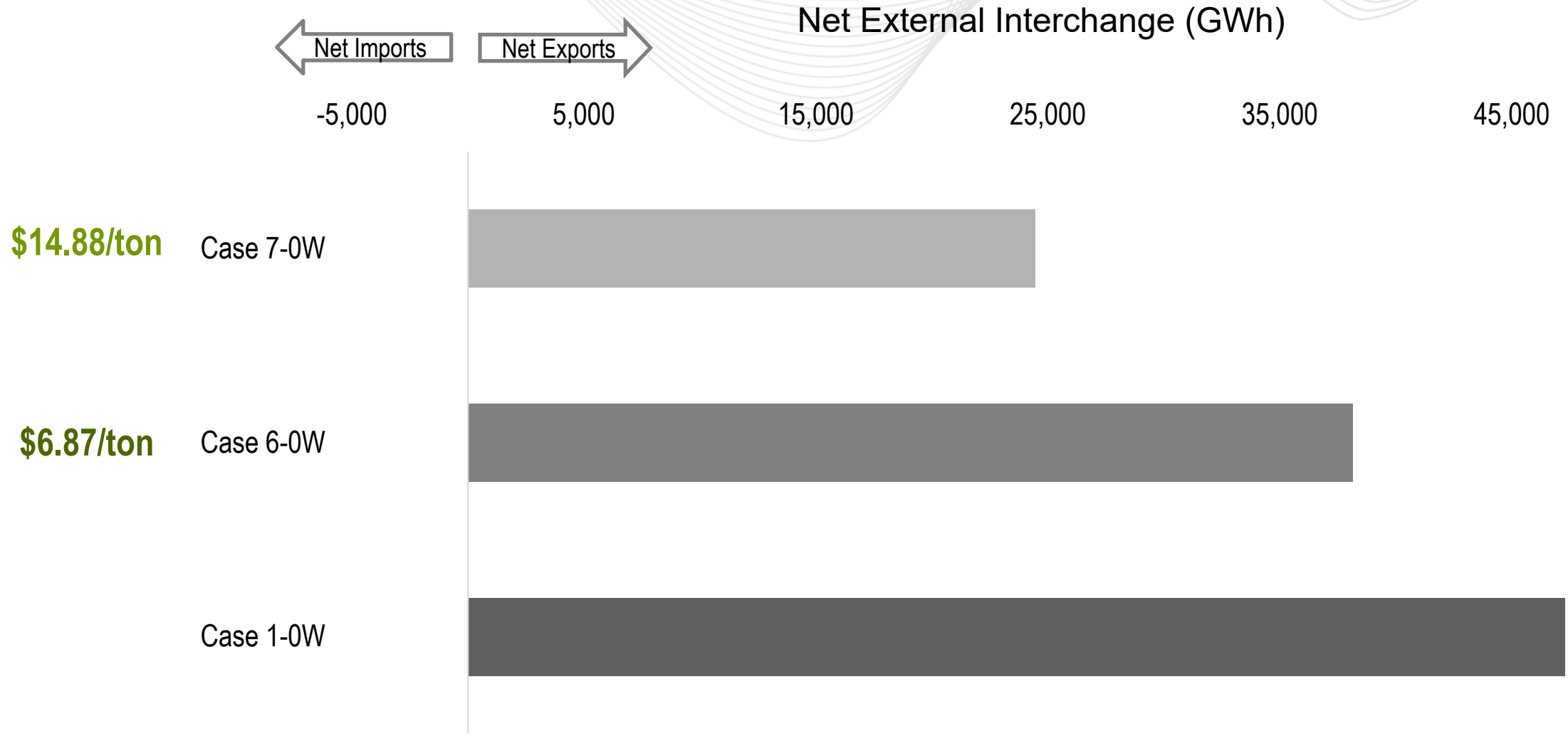


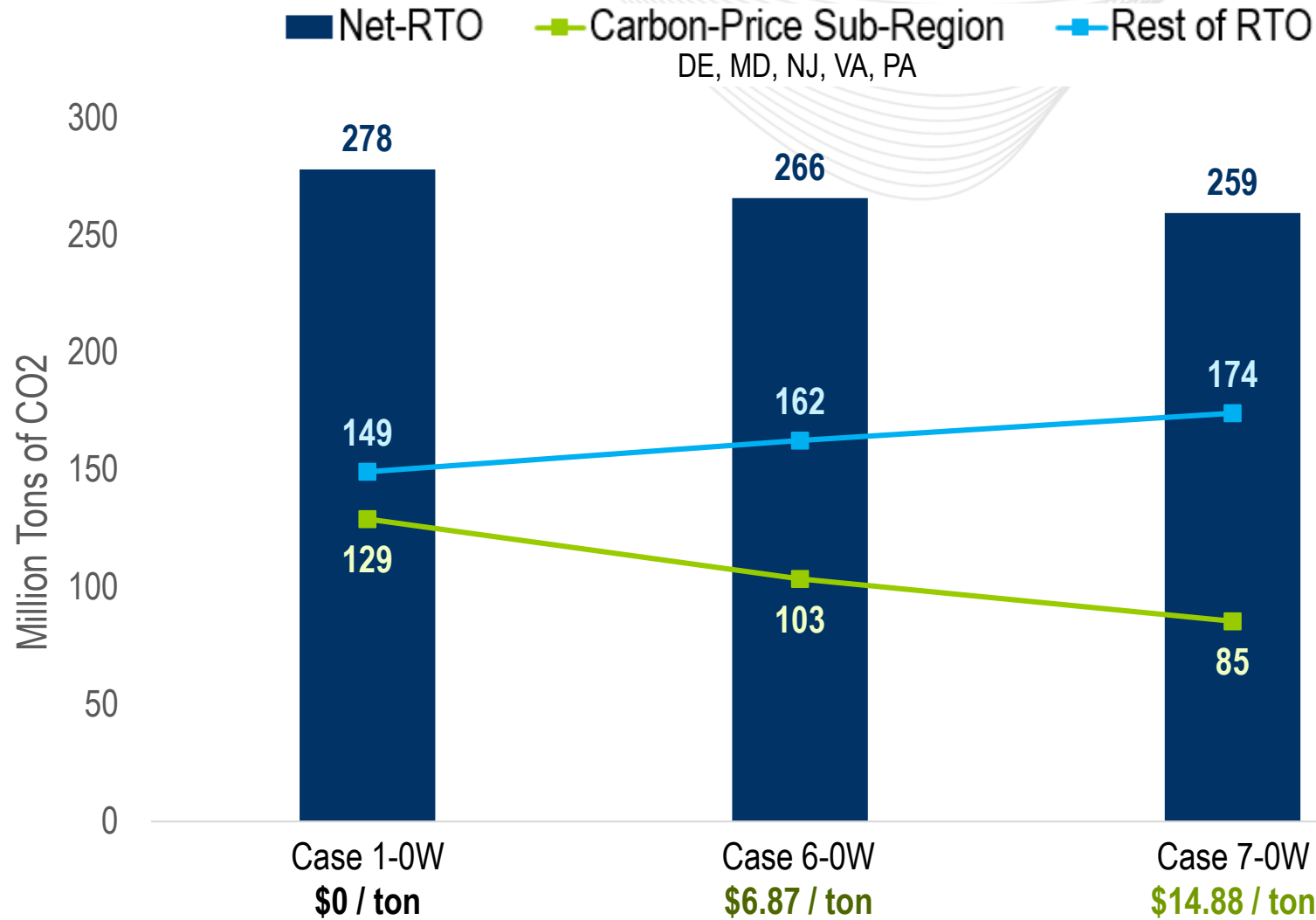
Generation displaced in carbon-price sub-region is relatively equivalent in emissions intensity to the increased generation in rest of RTO.

- Driven by generation mixes in each sub-region.



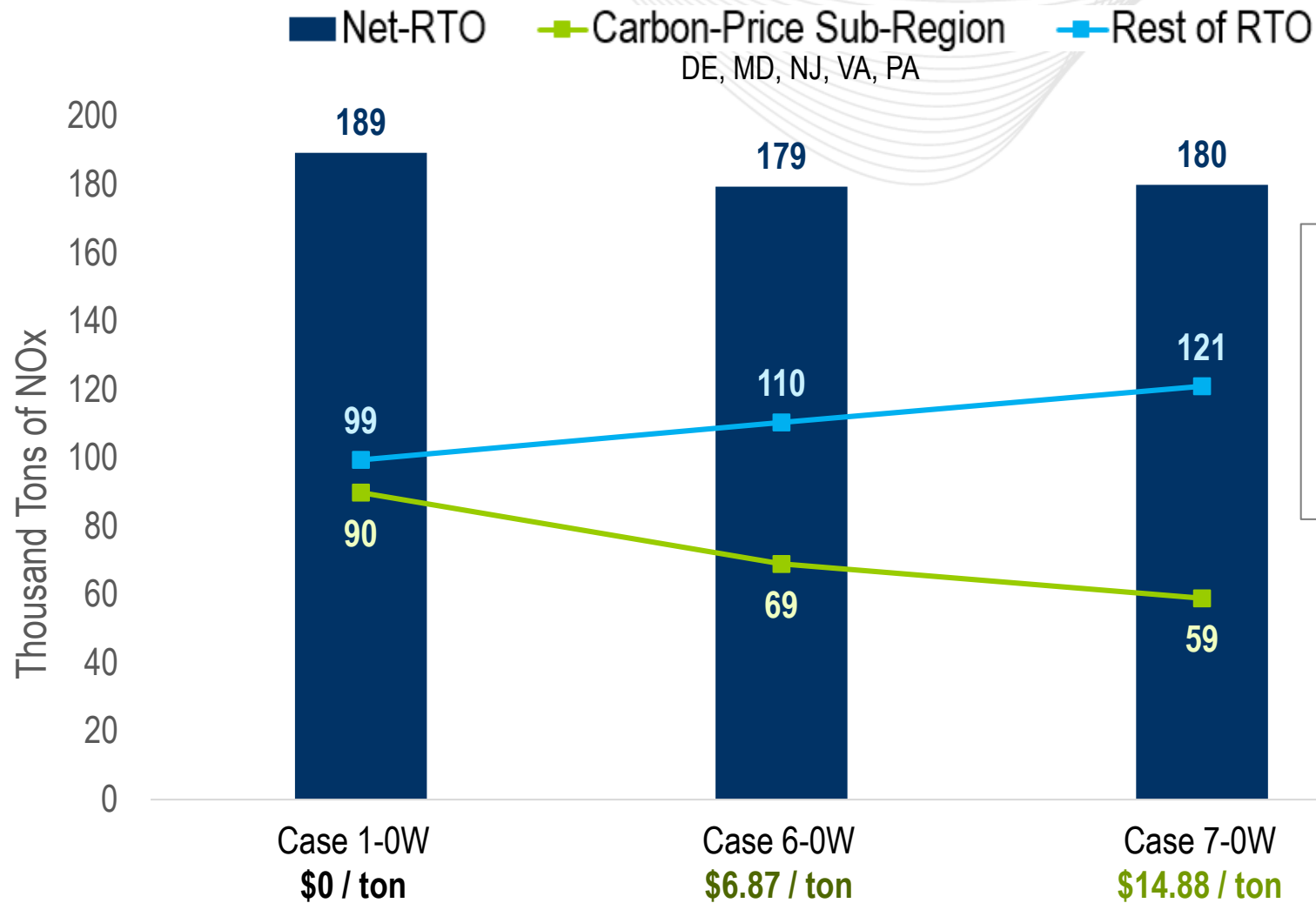
Interchange between PJM and External Regions





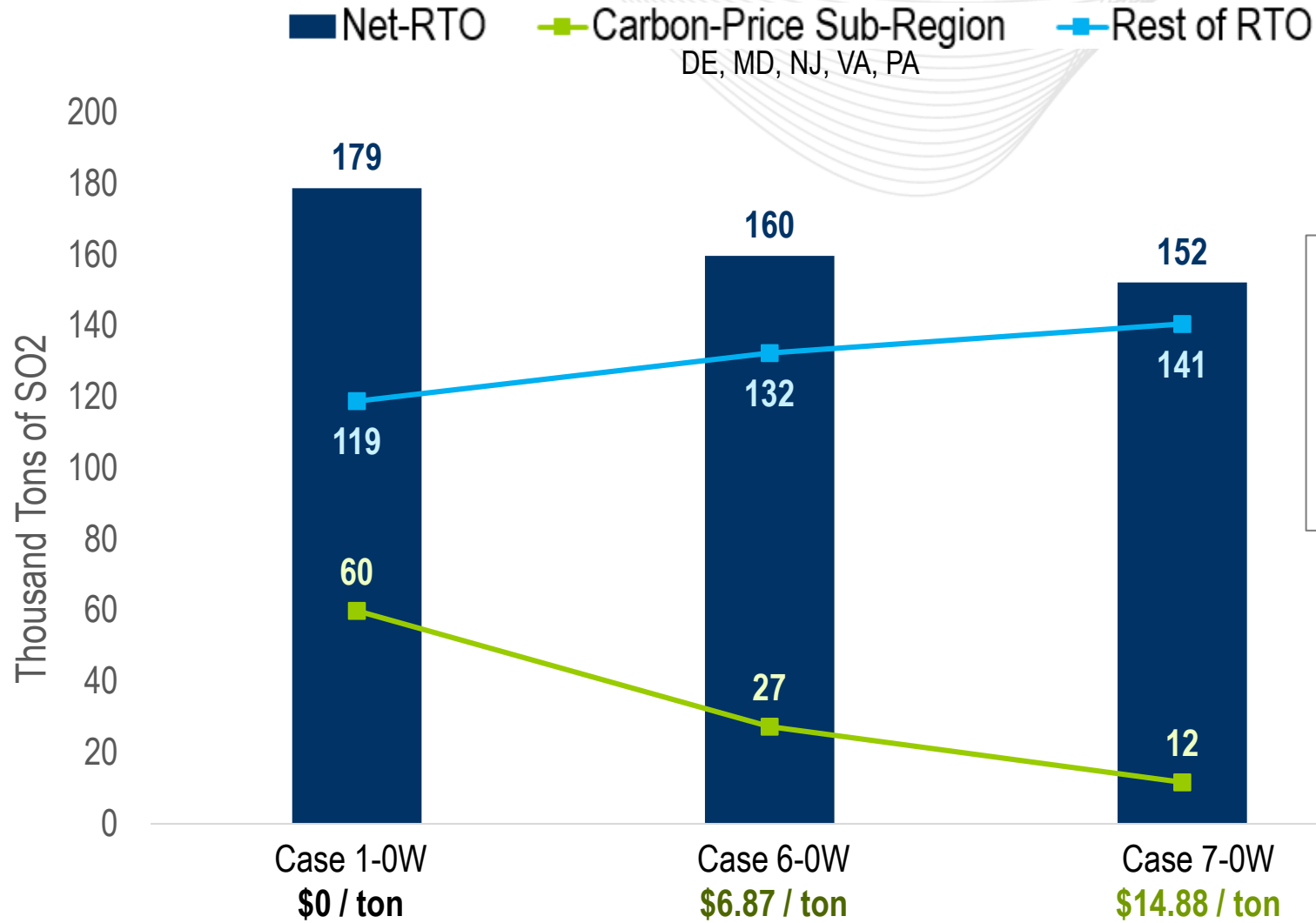
Generation shift from increasing carbon price results in CO₂:

- *Decrease* in carbon-price sub-region
- *Increase* in rest of RTO (no carbon price)
- *Net decrease* across the RTO



Generation shift from increasing carbon price results in CO₂:

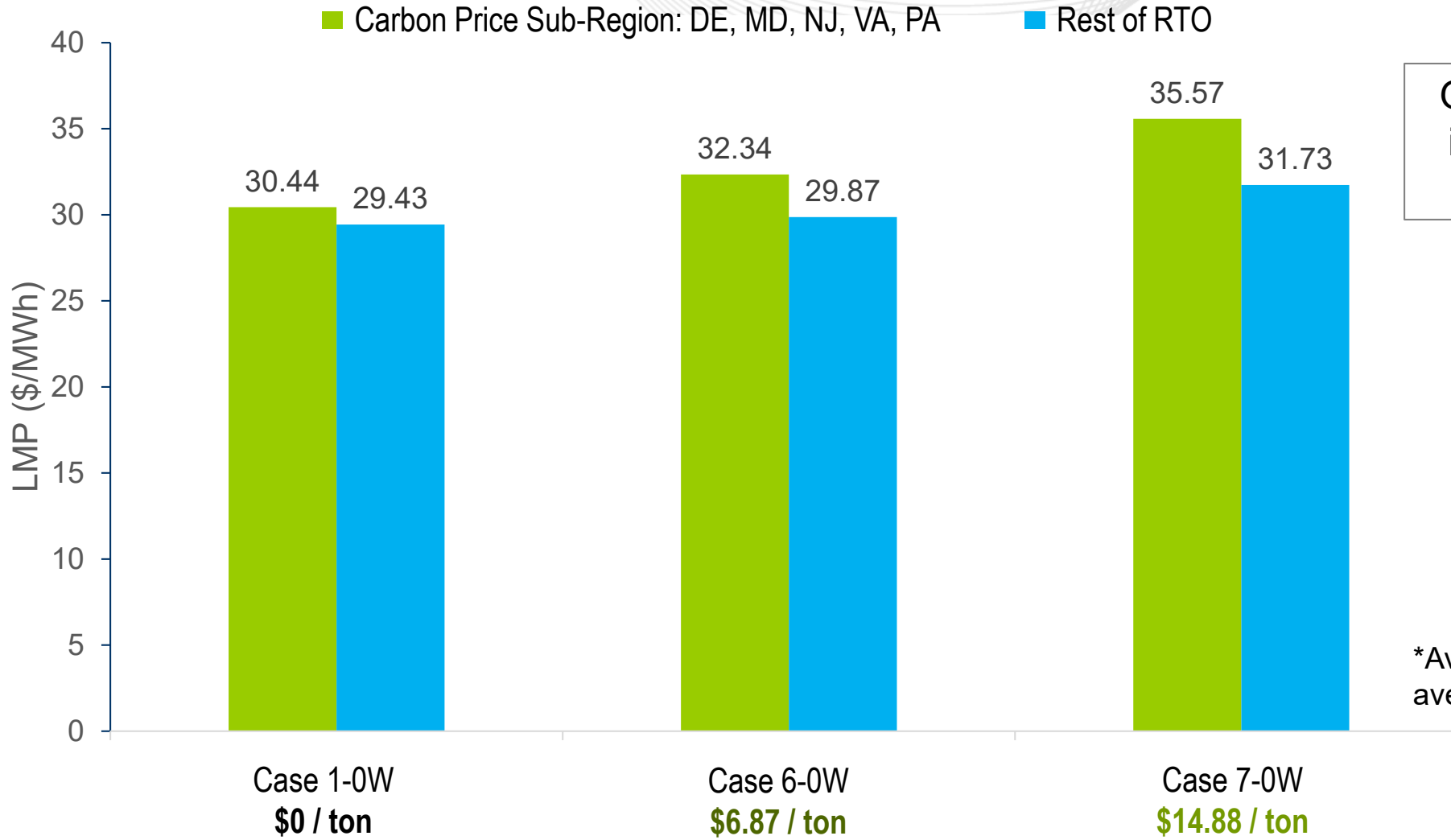
- *Decrease* in carbon-price sub-region
- *Increase* in rest of RTO
- *Net decrease* across the RTO



Generation shift from increasing carbon price results in CO₂:

- *Decrease* in carbon-price sub-region
- *Increase* in rest of RTO (no carbon price)
- *Net decrease* across the RTO

2023 PJM Average Yearly LMPs* by Sub-Region & Carbon Price

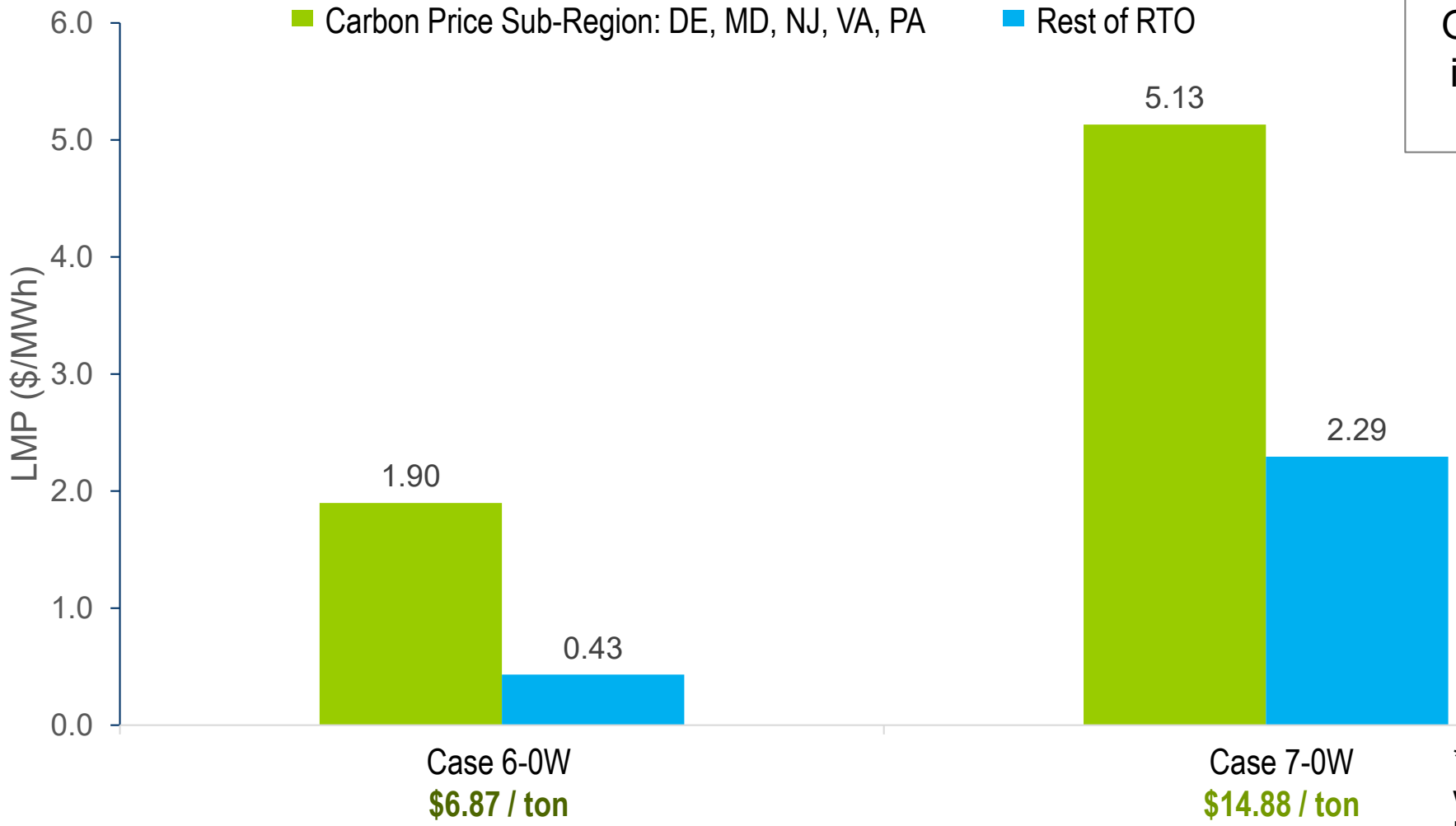


On average, LMPs increase in both sub-regions with an increasing carbon price.

*Average yearly LMPs are time-weighted averages of load-weighted hourly LMPs.



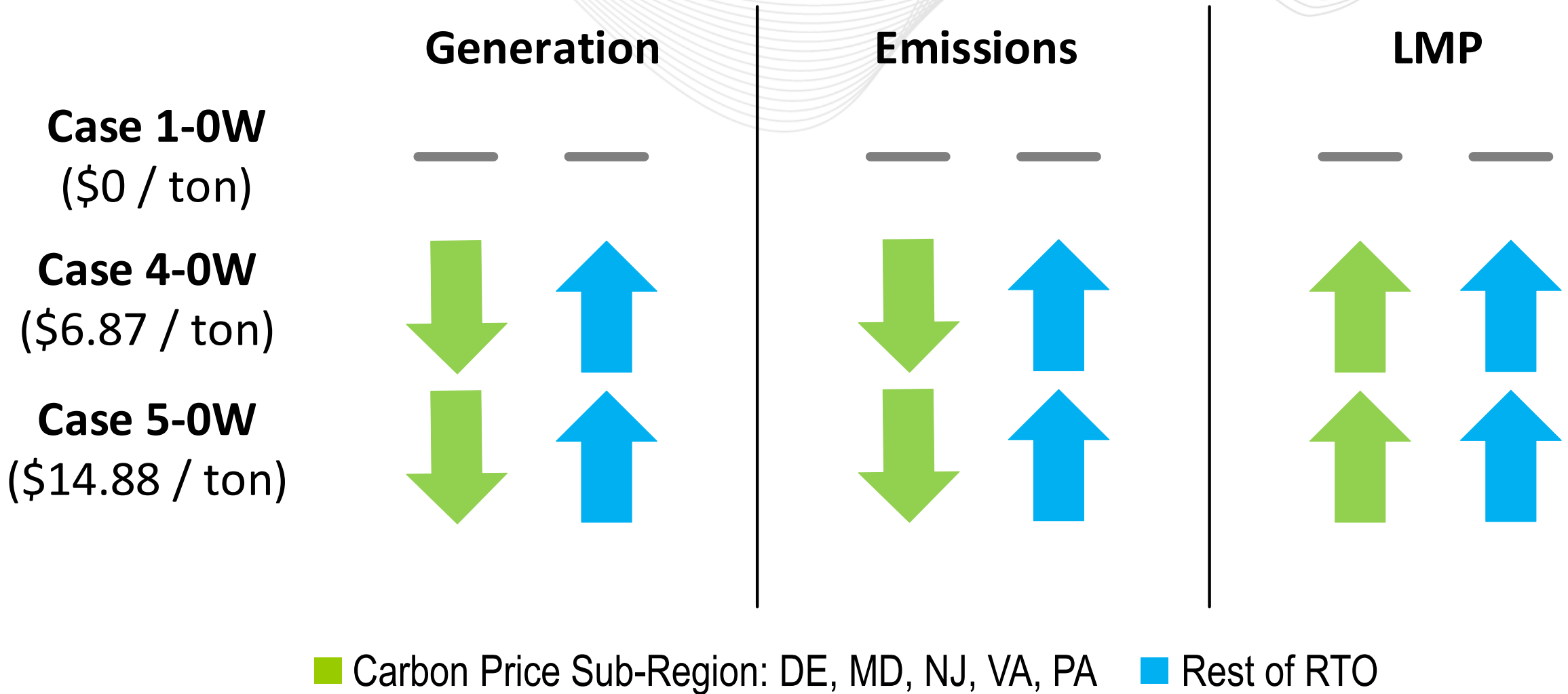
2023 Difference in Average Yearly LMPs* from Case 1-0W by Sub-Region & Carbon Price



On average, LMPs increase in both sub-regions with an increasing carbon price.

*Average yearly LMPs are time-weighted averages of load-weighted hourly LMPs.

Part 1b: Impacts Associated with a RGGI Carbon Price in the PJM Energy Market



- **Generation:**

- Compared to the no carbon price scenario, the carbon price scenarios result in shifts in generation production from the Carbon-Price Sub-Region to the Rest of RTO.
- The generation displaced in the Carbon-Price Sub-Region has relatively equivalent emissions intensity compared to the increased generation in the Rest of RTO. This is driven by the generation mixes between of each sub-region.

- **Emissions:**

- The shift in generation production results in a decrease in emissions in the Carbon-Price Sub-Region, an increase in emissions in the Rest of RTO, and a net decrease in Net-RTO emissions.

- **Energy Prices:**

- Compared to the scenario with no carbon price, on average, LMPs increase in both sub-regions as the carbon price increases.

Review of Context, Objectives, and Study Assumptions

Part 1a: Impacts of a RGGI Carbon Price in the PJM Energy Market; Addition of VA to carbon-price sub-region

Part 2a: Impacts of Potential Border Adjustments for Leakage Mitigation; Addition of VA to carbon-price sub-region

Part 1b: Impacts of a RGGI Carbon Price in the PJM Energy Market; Addition of VA & PA to carbon-price sub-region

Part 2b: Impacts of Potential Border Adjustments for Leakage Mitigation; Addition of VA & PA to carbon-price sub-region

- The year 2023 was simulated for the following cases for the carbon-price sub-region that included DE, MD, NJ, VA and PA:

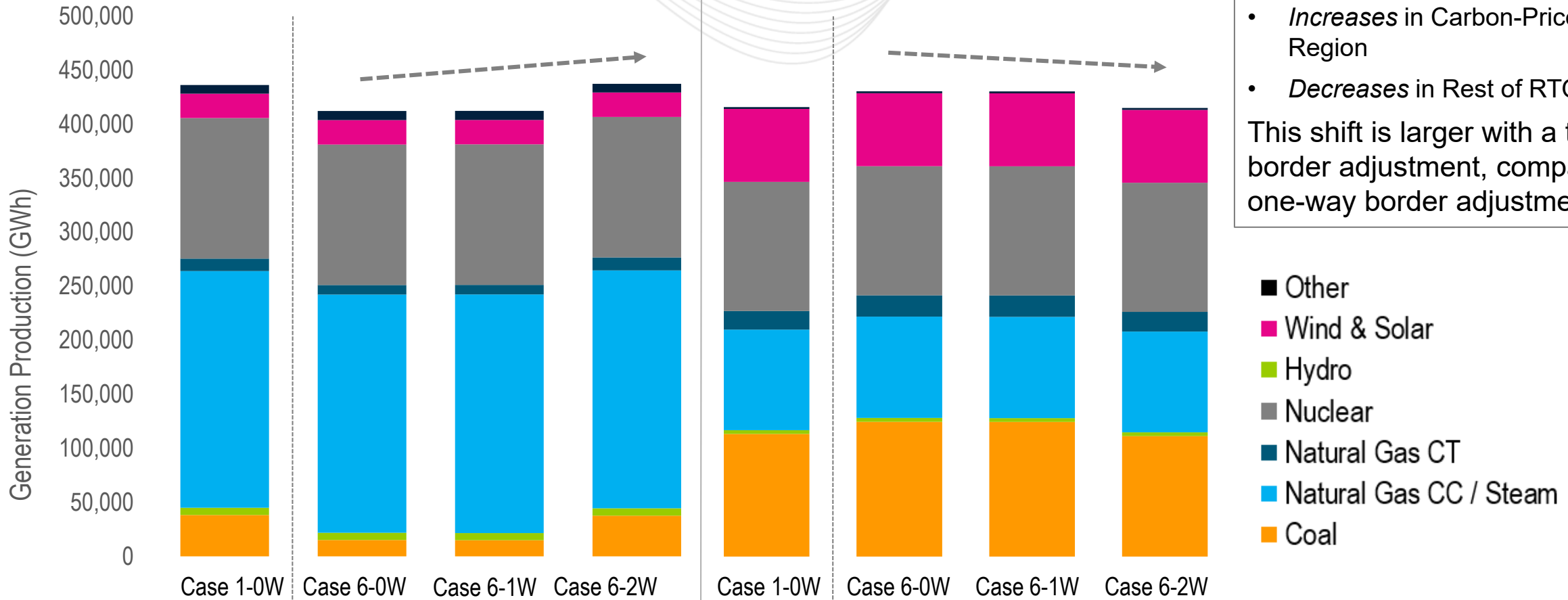
Case	RGGI Price	Border Adjustment
Case 6-0W	\$6.87/short ton	None
Case 6-1W	\$6.87/short ton	One-Way
Case 6-2W	\$6.87/short ton	Two-Way
Case 7-0W	\$14.88/short ton	None
Case 7-1W	\$14.88/short ton	One-Way
Case 7-2W	\$14.88/short ton	Two-Way

- The following metrics are compared for each simulation case:
 - Generation
 - Emissions
 - Prices
 - Carbon Revenue (Residual Funds)
- Results are broken out by the following regions:
 - Carbon-Price Sub-Region – includes **DE, MD, NJ, VA and PA**
 - Rest of RTO – all other states in PJM

2023 Generation Production by Sub-Region: \$6.87 / ton CO₂

Carbon-Price Sub-Region (DE, MD, NJ, VA, PA)

Rest of RTO



With the addition of a border adjustment, generation:

- *Increases* in Carbon-Price Sub-Region
- *Decreases* in Rest of RTO

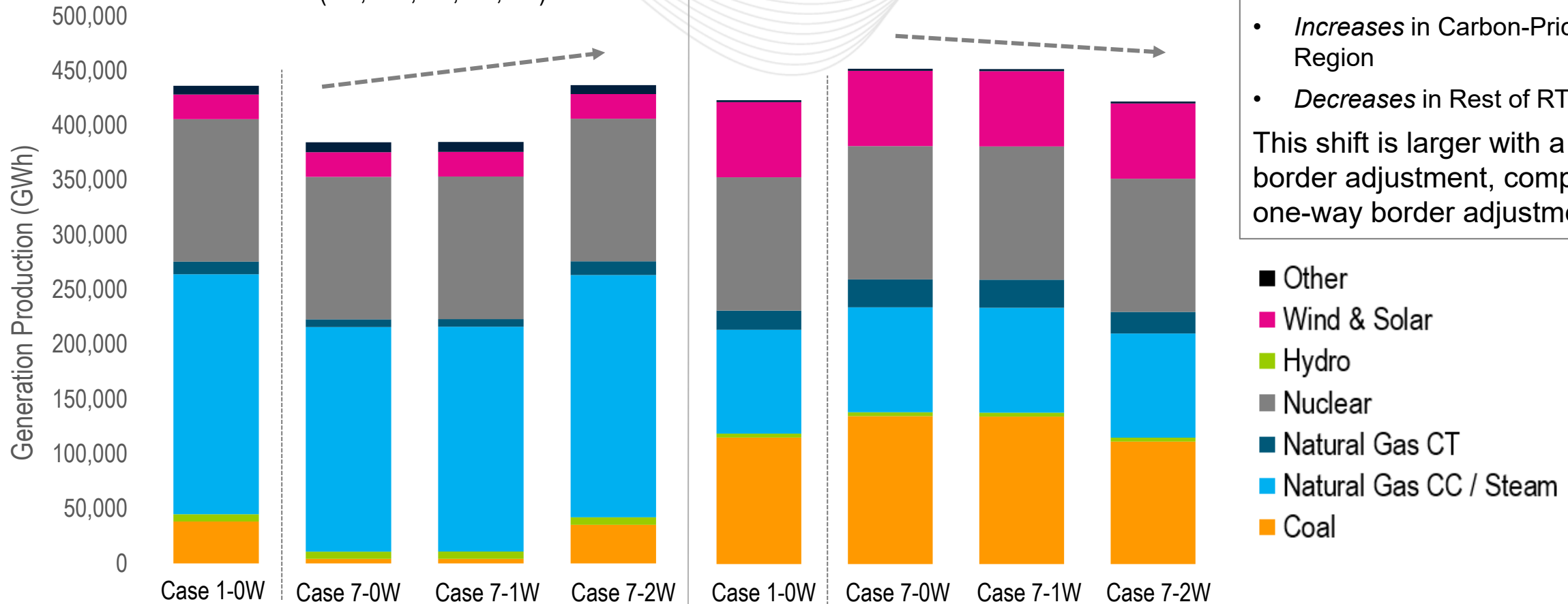
This shift is larger with a two-way border adjustment, compared to a one-way border adjustment.



2023 Generation Production by Sub-Region: \$14.88 / ton CO₂

Carbon-Price Sub-Region (DE, MD, NJ, VA, PA)

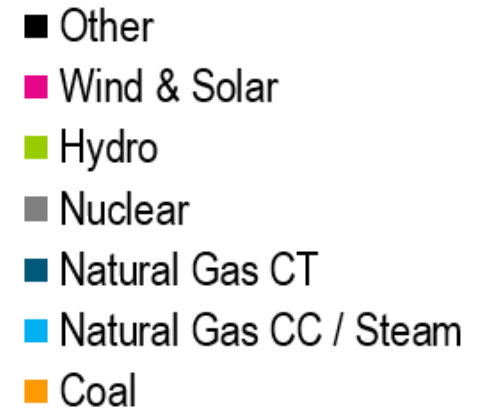
Rest of RTO



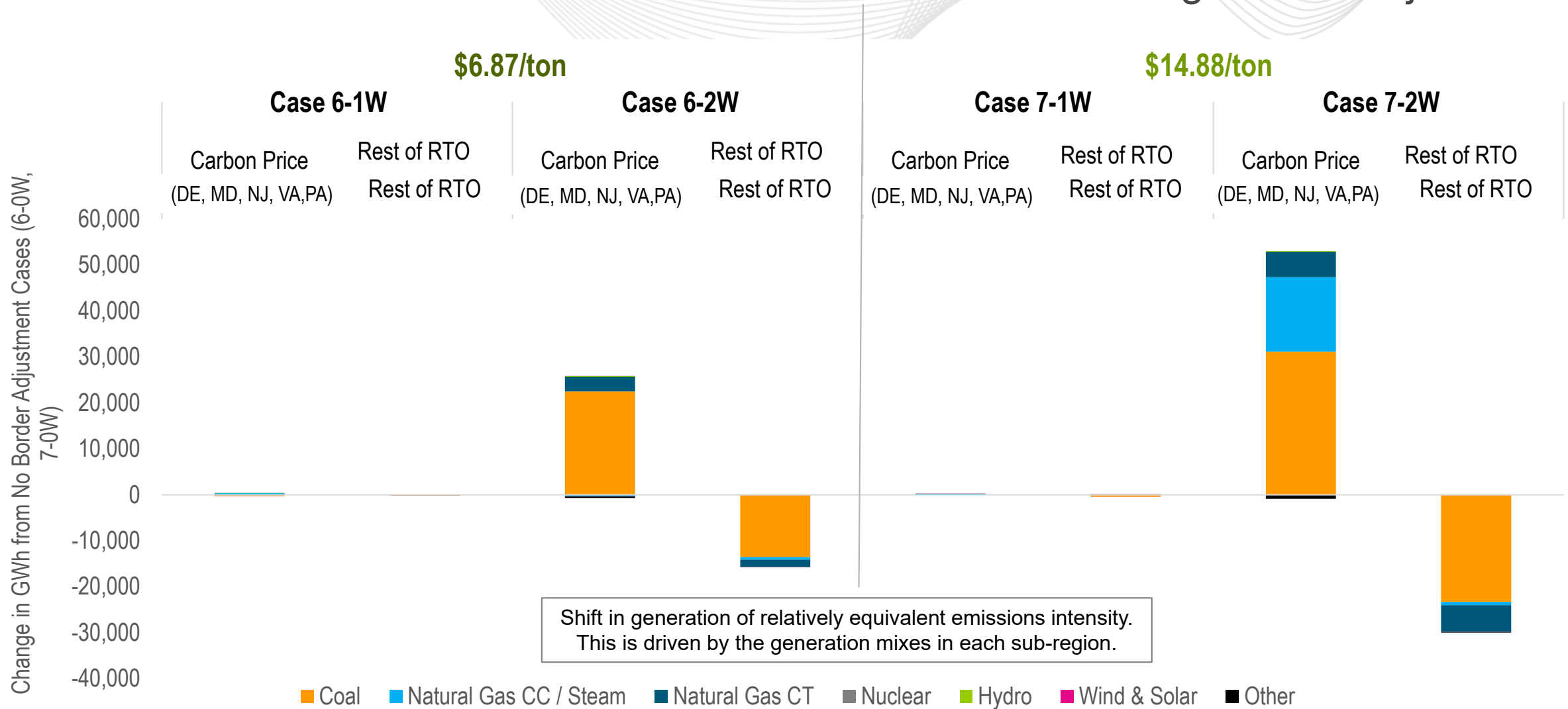
With the addition of a border adjustment, generation:

- *Increases* in Carbon-Price Sub-Region
- *Decreases* in Rest of RTO

This shift is larger with a two-way border adjustment, compared to a one-way border adjustment.

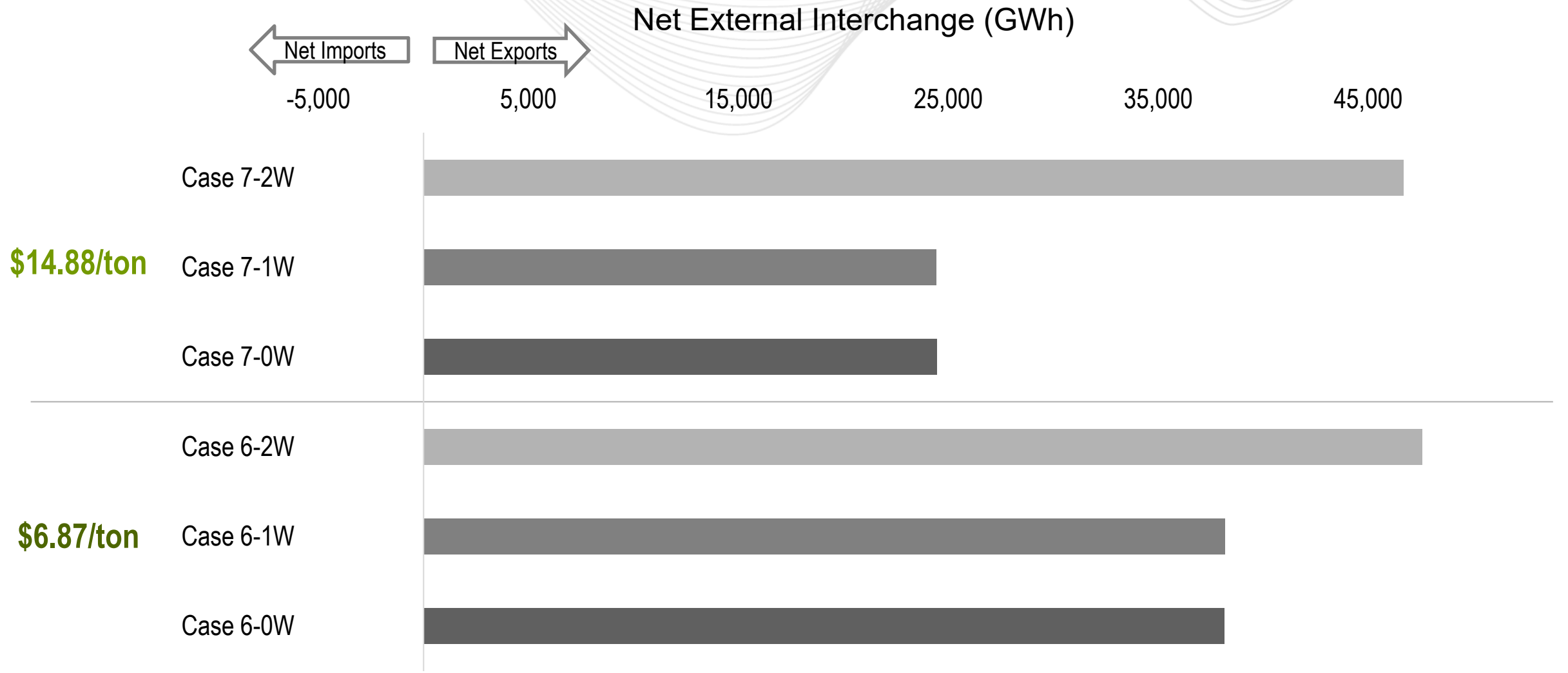


Shift in Generation Production by Sub-Region from adding Border Adjustment



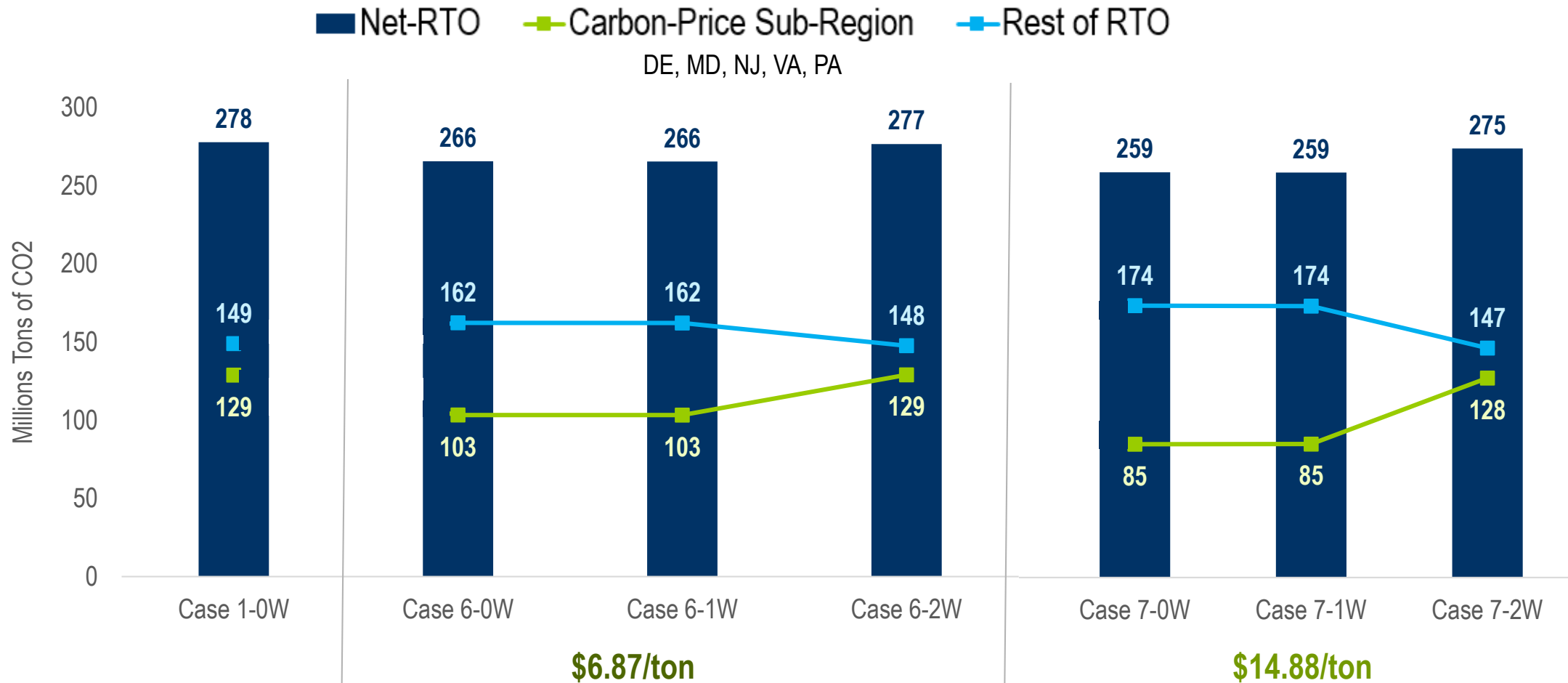


Interchange between PJM and External Regions



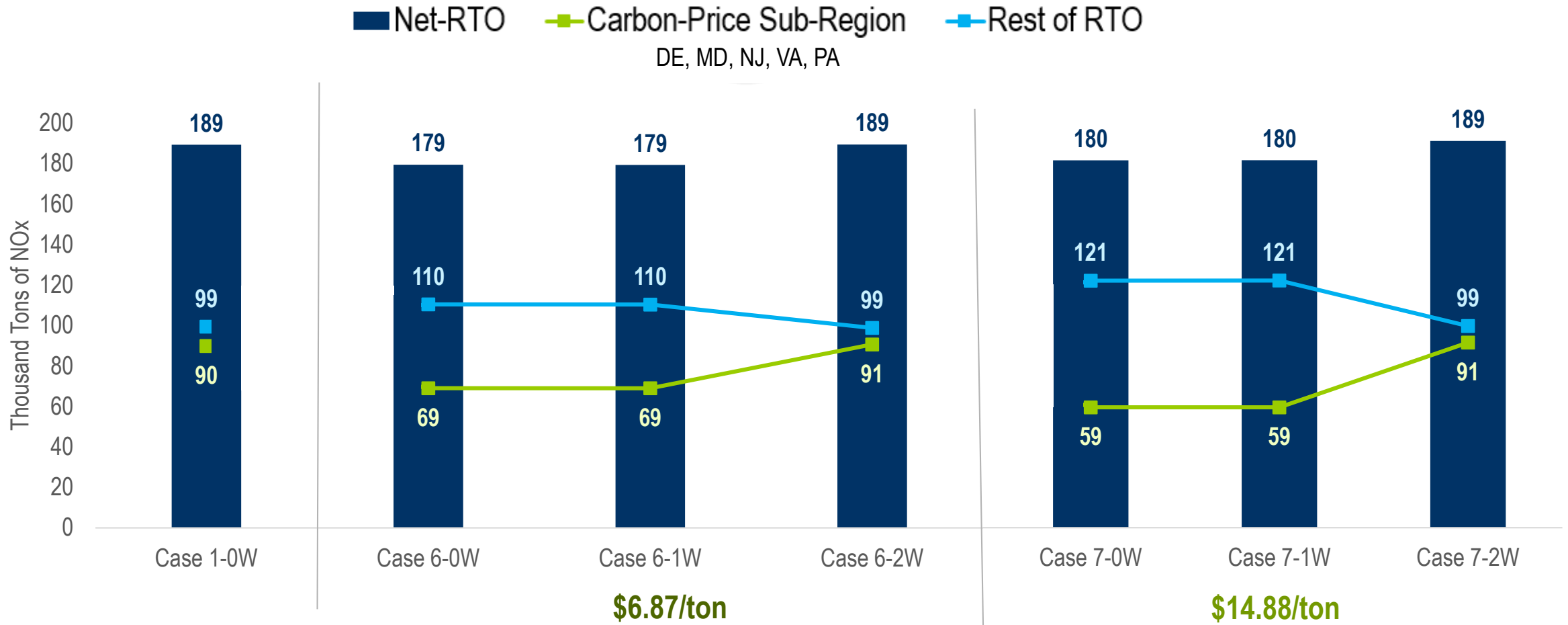
Impact of Border Adjustment on CO₂ Emissions

Generation shift from one-way border adjustment results in small emissions shifts between sub-regions, and small *net decrease* across Net-RTO. Two-way border adjustment results in emissions *increase* in Carbon-Price Sub-Region, *decrease* in Rest of RTO and *net increase* across Net-RTO.



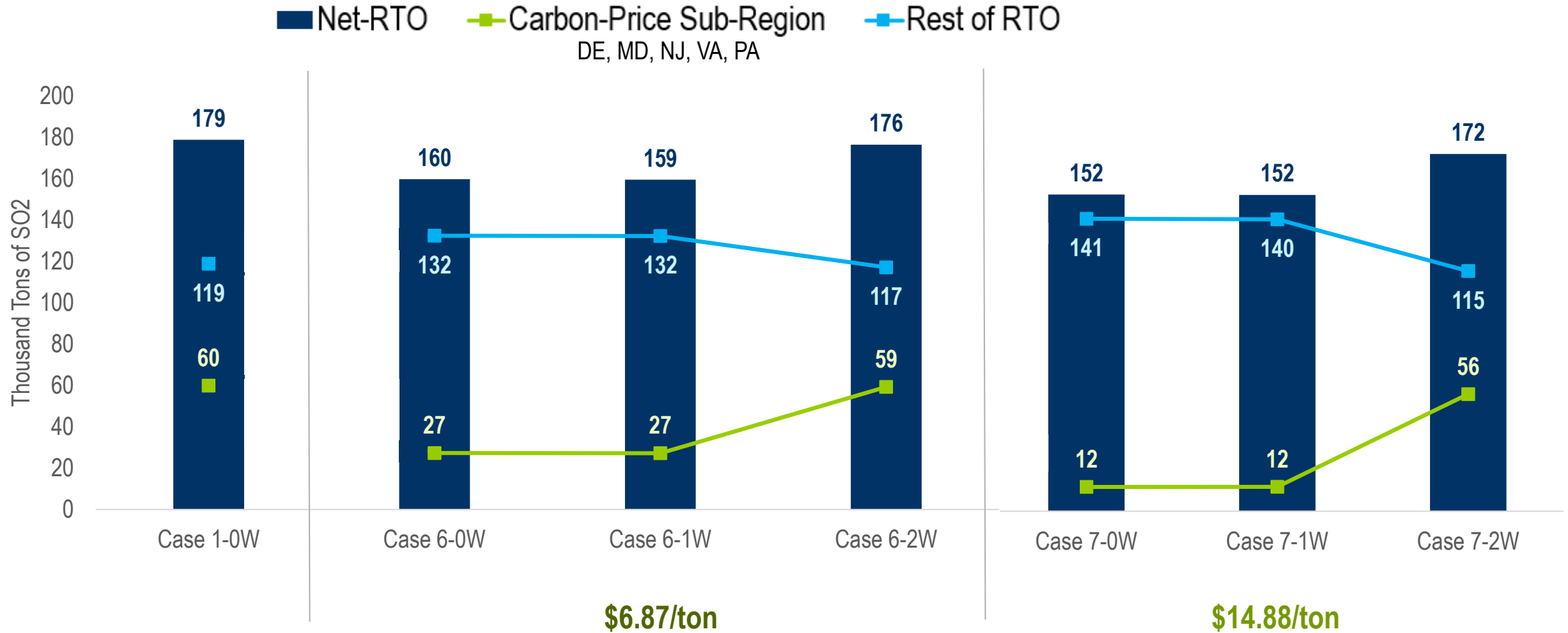
Impact of Border Adjustment on NO_x Emissions

Generation shift from one-way border adjustment results in small emissions shifts between sub-regions, and small *net decrease* across Net-RTO. Two-way border adjustment results in emissions *increase* in Carbon-Price Sub-Region, *decrease* in Rest of RTO and *net increase* across Net-RTO.



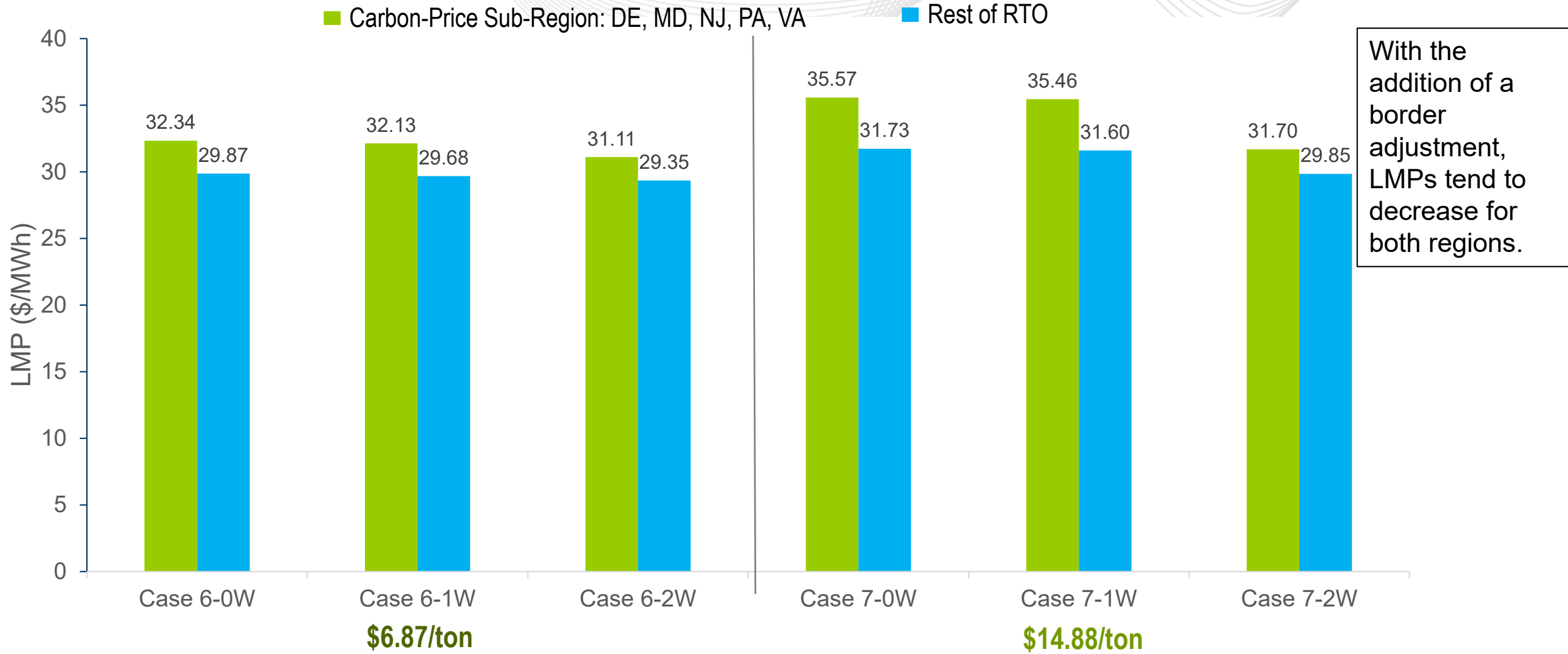
Impact of Border Adjustment on SO₂ Emissions

Generation shift from one-way border adjustment results in small emissions shifts between sub-regions, and small *net decrease* across Net-RTO. Two-way border adjustment results in emissions *increase* in Carbon-Price Sub-Region, *decrease* in Rest of RTO and *net increase* across Net-RTO.





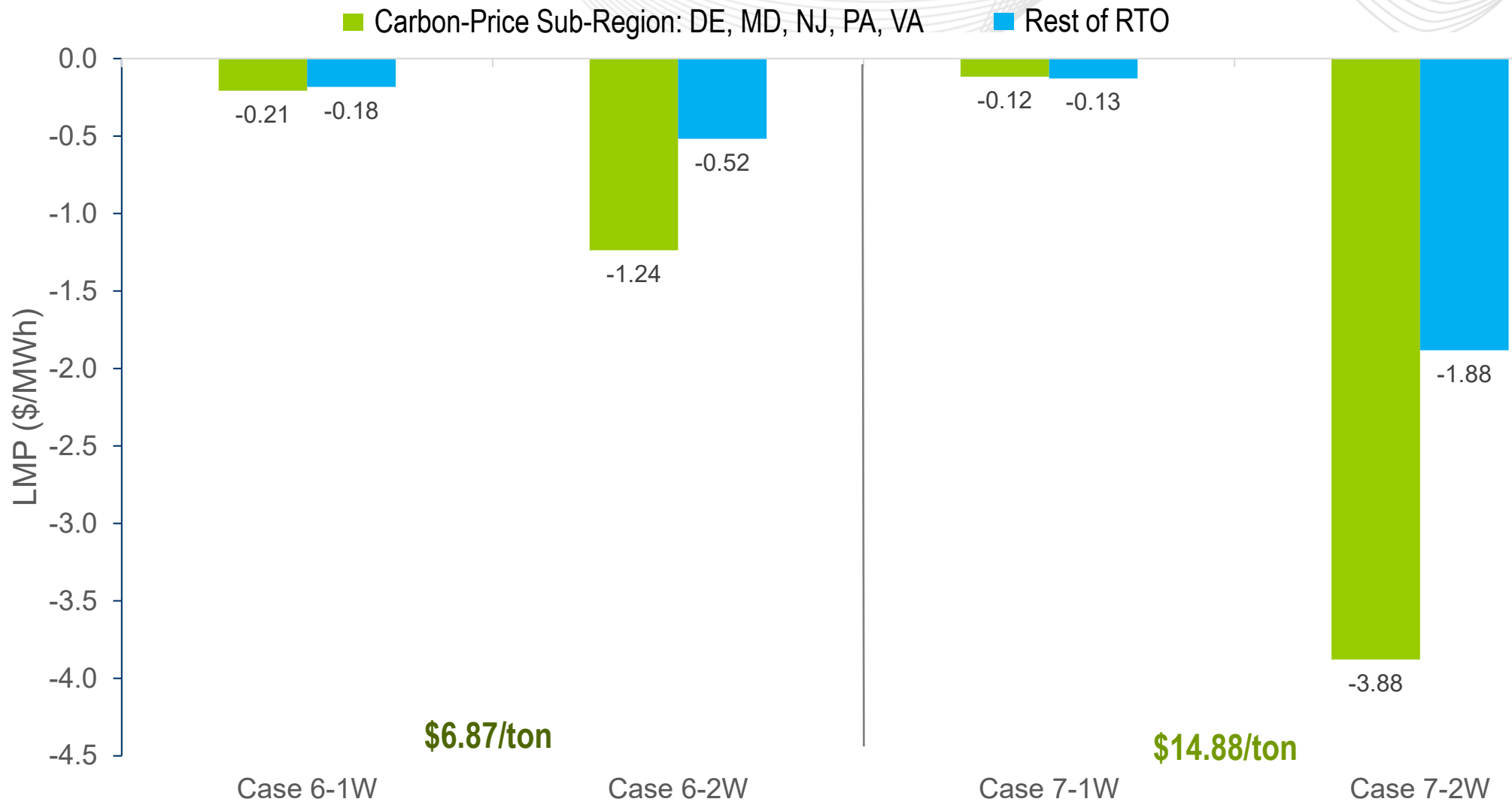
2023 PJM Average Yearly LMPs* by Sub-Region



*Average yearly LMPs are time-weighted averages of load-weighted hourly LMPs.



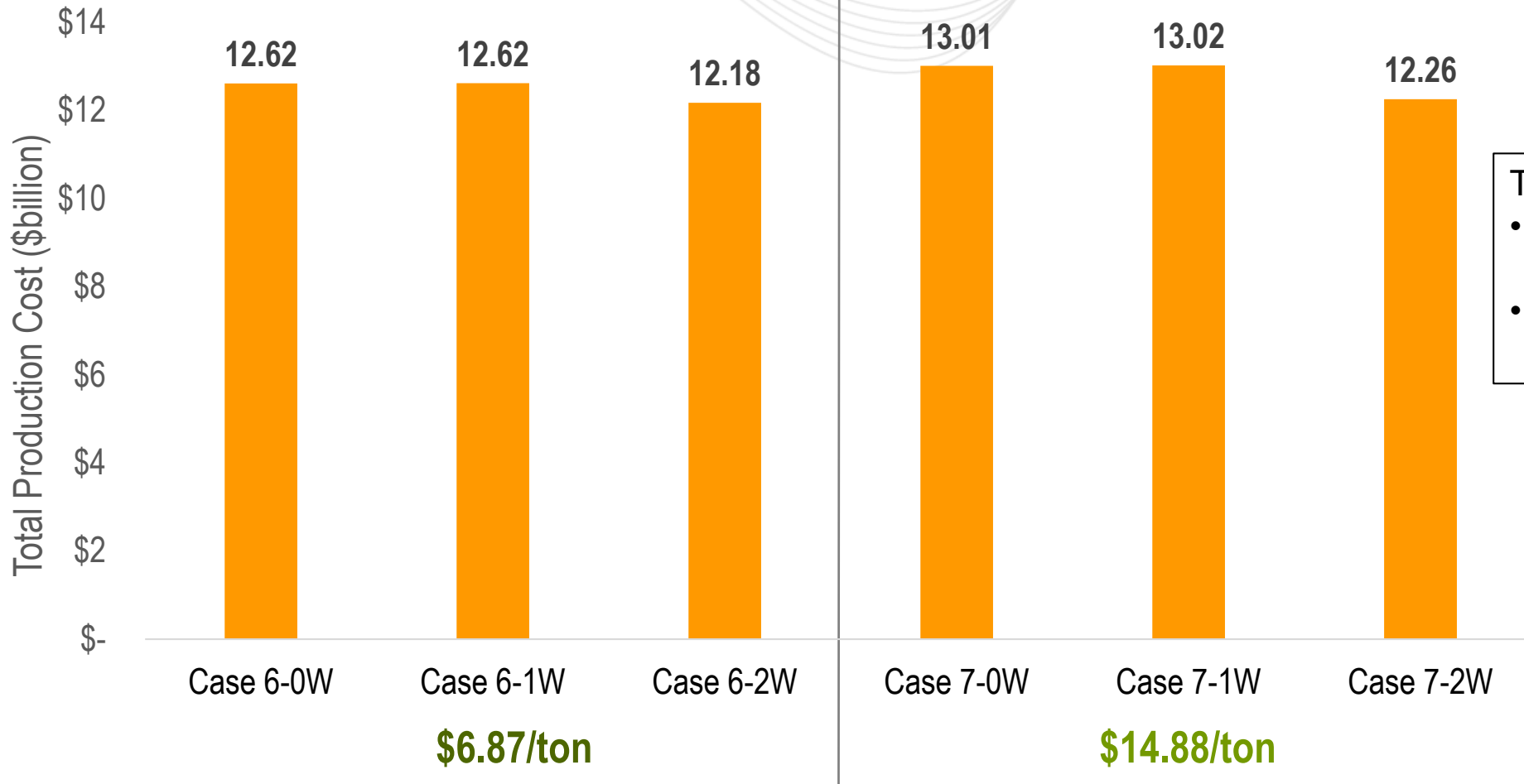
2023 Difference in Average Yearly LMPs* from Case 0W by Sub-Region and RGGI Price



With the addition of a border adjustment, LMPs tend to decrease for both regions.

*Average yearly LMPs are time-weighted averages of load-weighted hourly LMPs.

Impact of Border Adjustments on 2023 RTO Total Production Cost



Total System Production Cost:

- *Increases* with a one-way border adjustment
- *Decreases* with a two-way border adjustment

- As previously noted, compared to scenarios with no leakage mitigation, the border adjustment scenarios result in shifts in generation production from the Rest of RTO to the Carbon-Price Sub-Region.
- This could be assumed to increase the funds from CO₂ allowance sales that states would collect if the CO₂ compliance obligation continues to be placed on the emitting generators in their states.
- However, it is possible in the **two-way** border adjustment case, that generators will not receive enough revenue through the market to cover their RGGI compliance obligations (which are paid outside the market) and generation costs.

- In all simulation cases, there are no carbon residual funds at any time.
- This is because the carbon component of the LMP is \$0/MWh at all times in all cases.
- In other words, the carbon cost of the marginal unit being transferred from the Rest of RTO Sub-Region to the Carbon-Price Sub-Region is zero in all the simulation cases.

Part 2b: Impacts of Potential Border Adjustments for Leakage Mitigation

	Generation		Emissions		LMP	
Case 4-0W (\$6.87 / ton)	—	—	—	—	—	—
Case 4-1W (\$6.87 / ton)	↑	↓	↑	↓	↓	↓
Case 4-2W (\$6.87 / ton)	↑	↓	↑	↓	↓	↓
Case 5-0W (\$14.88 / ton)	—	—	—	—	—	—
Case 5-1W (\$14.88 / ton)	↑	↓	↑	↓	↓	↓
Case 5-2W (\$14.88 / ton)	↑	↓	↑	↓	↓	↓

■ Carbon Price Sub-Region: DE, MD, NJ, PA, VA

■ Rest of RTO

- **Generation:**

- Compared to scenarios with no leakage mitigation, the border adjustment scenarios result in shifts in generation production from the Rest of RTO to the Carbon-Price Sub-Region.
- This generation shift increases as the price of carbon increases, and is greater with a two-way border adjustment, compared to a one-way border adjustment.
- The generation displaced in the Rest of RTO is of relatively equivalent emissions intensity to the increased generation in the Carbon-Price Sub-Region. This is reflective of the in generation mixes in each sub-regions.

- **Emissions:**

- Use of a one-way border adjustment mechanism resulted in an increase in emissions in the Carbon-Price Sub-Region, a decrease in emissions in the Rest of RTO, and a *net decrease* in total Net-RTO emissions.
- Use of a two-way border adjustment mechanism resulted in an increase in emissions in the Carbon-Price Sub-Region, a decrease in emissions in the Rest of RTO, and a *net increase* in total Net-RTO emissions.
- The change in emissions is greater as the carbon price increases.

- **Energy Prices:**

- Use of a border adjustment mechanism may mitigate the impact of a carbon price on the LMP.
- Compared to scenarios with no leakage mitigation, on average, as the carbon price increases, a two-way border adjustment results in greater price decreases than a one-way border adjustment.

Results depend on the generation mix, and emissions intensities, of each sub-region.

Modeling of Carbon Prices from RGGI

Compared to counterfactual with no carbon price

- Generation & Emissions
 - **Decrease** in carbon-price sub-region
 - **Increase** in rest of RTO
 - Net RTO impact varies based on sub-region assumptions

- Energy Prices
 - On average, LMPs **increase** in both sub-regions as the carbon price increases

Impacts of Border Adjustments

Compared to no border adjustment

- Generation & Emissions
 - **Increase** in carbon-price sub-region
 - **Decrease** in rest of RTO
 - Net RTO impact varies based on sub-region assumptions

- Energy Prices
 - On average, as the carbon price increases, a two-way border adjustment results in greater price **decreases** than a one-way border adjustment.