PJM Study of Carbon Pricing & Potential Leakage Mitigation Mechanisms

Carbon Pricing Senior Task Force

January 14, 2020

Overview

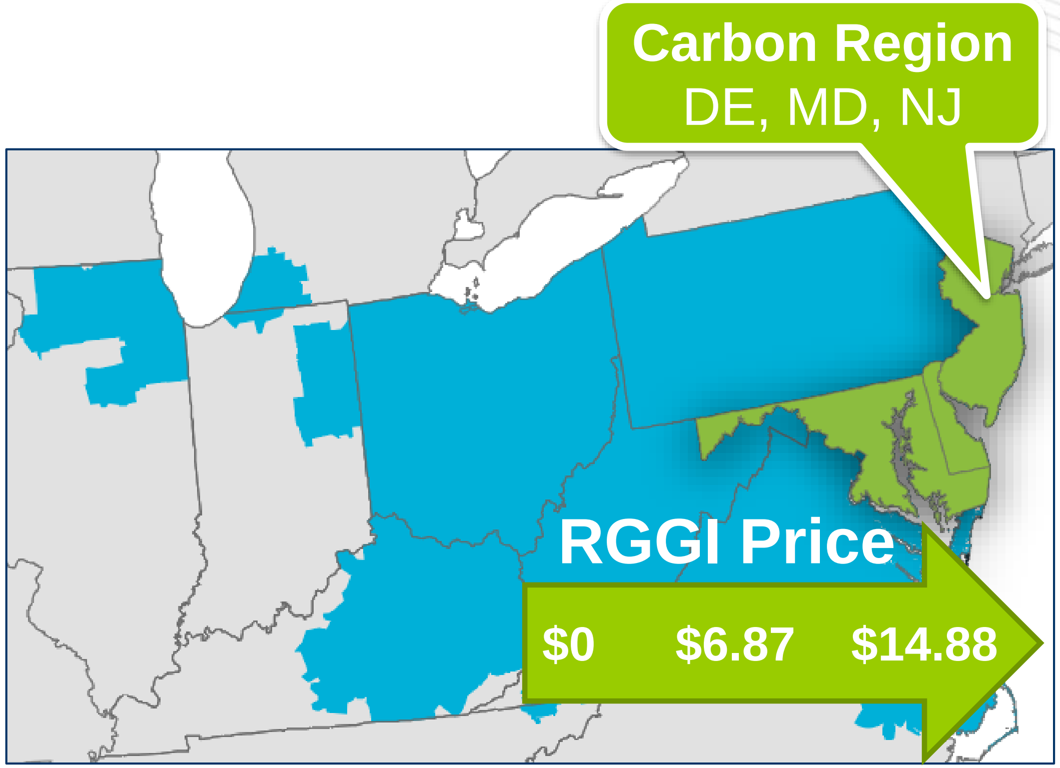
Executive Summary

Context, Objectives, and Study Assumptions

Results Part 1: Impacts of a RGGI Carbon Price in the PJM Energy Market

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

Study on Carbon Pricing & Potential Leakage Mitigation



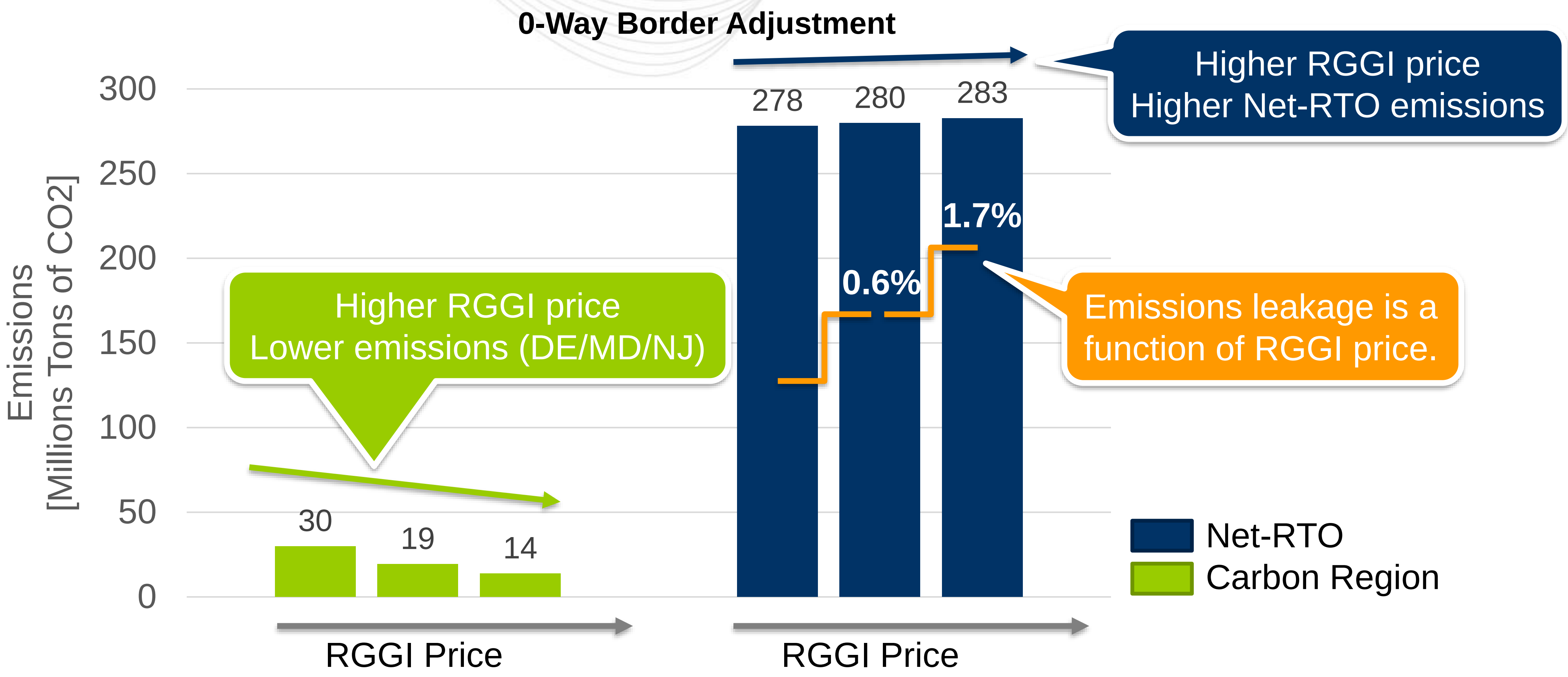
What It Is…

- Production-Cost Model
- Emission Leakage and Impact on LMP
- Border Adjustment: An Option for Leakage Mitigation

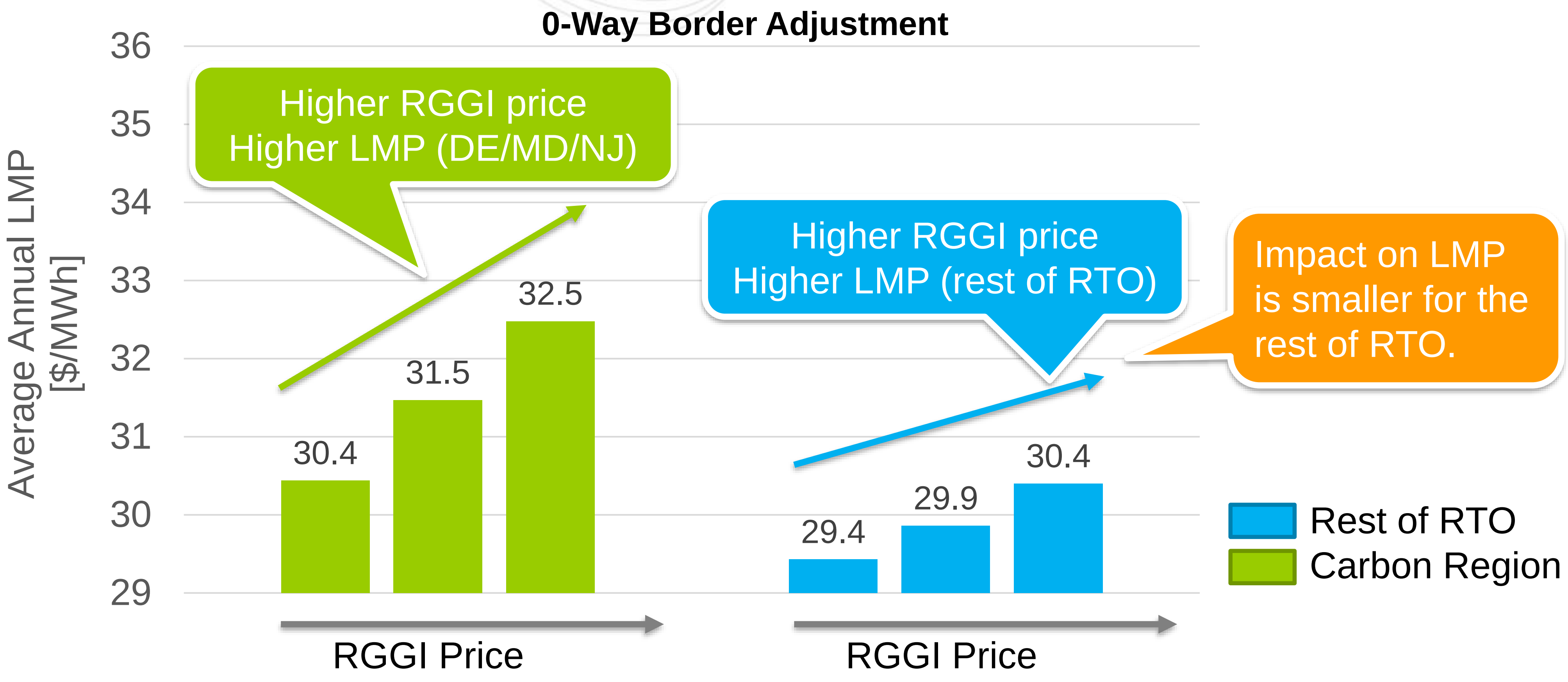
What It Is NOT…

- Macroeconomic
- State Policy
- PJM is ***NOT*** proposing to establish a carbon price or policy.

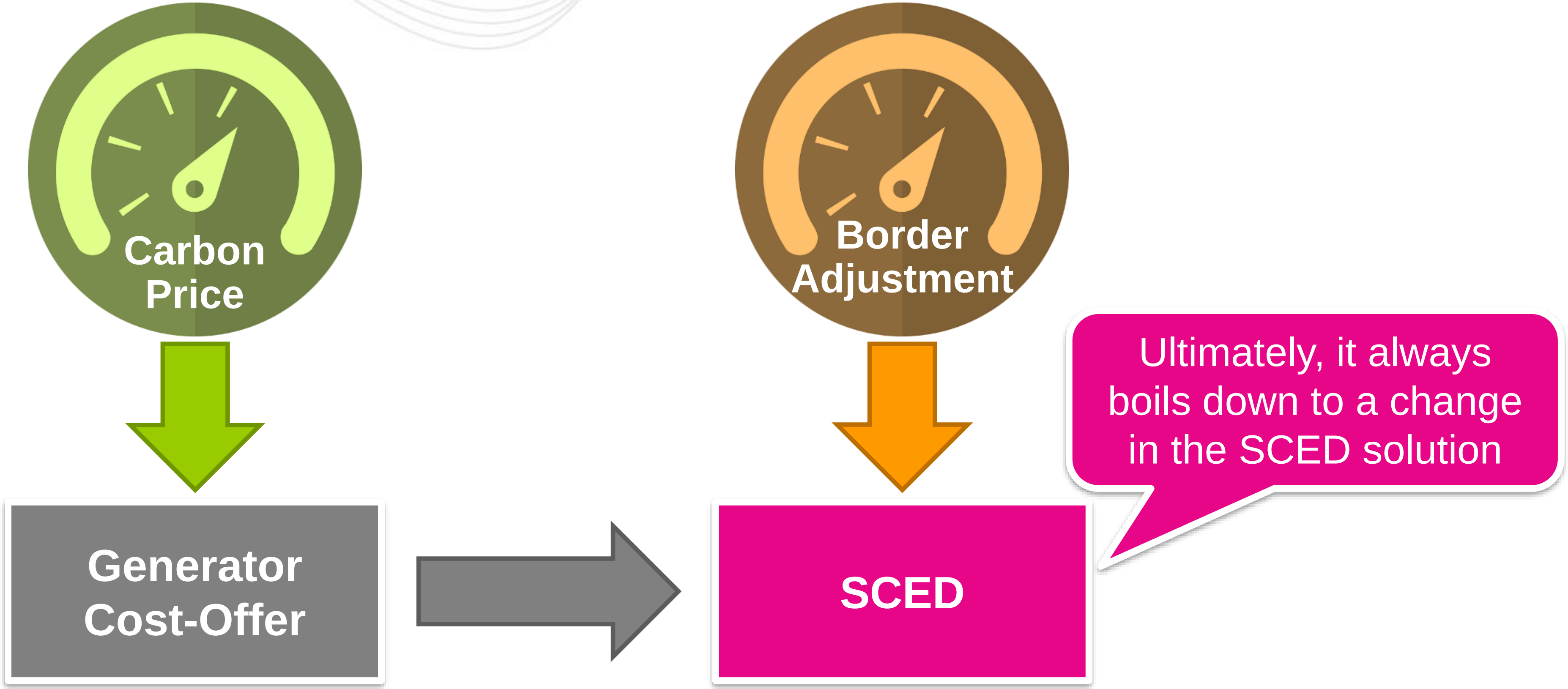
RGGI Impact on Emissions (No Border Adjustment)



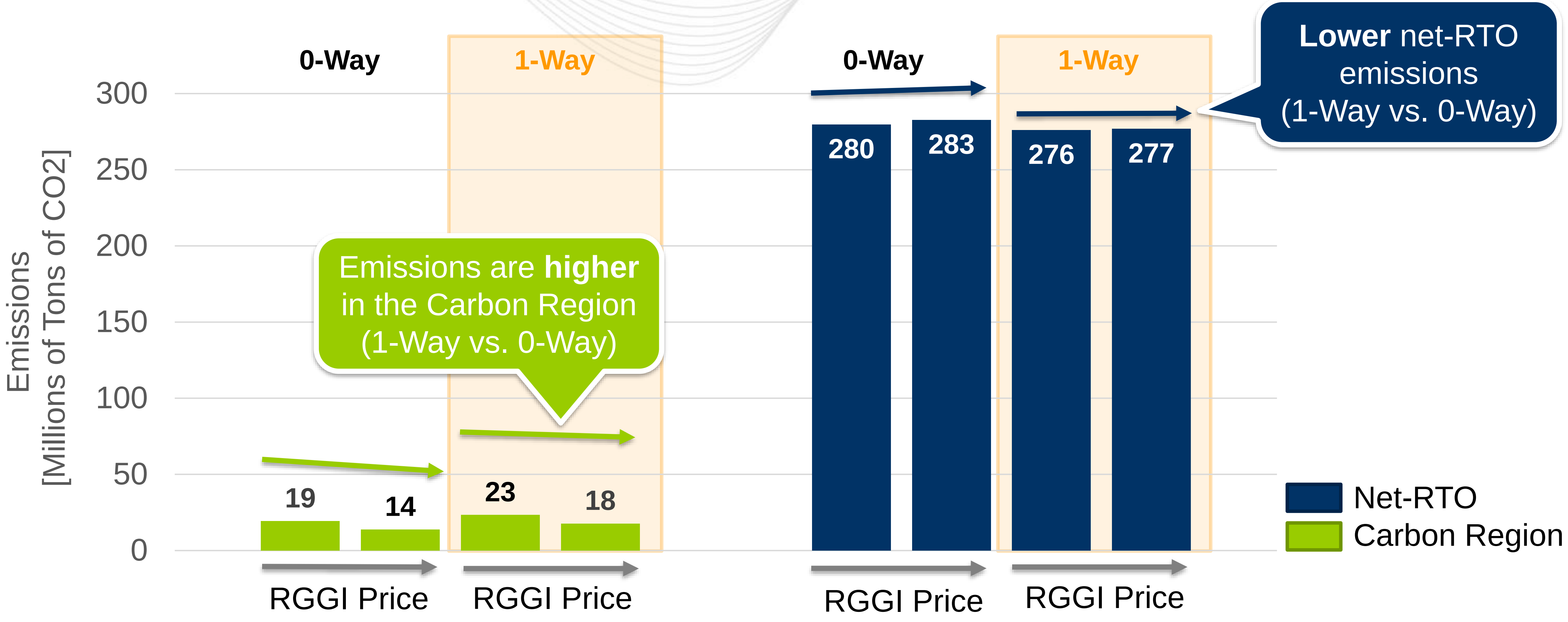
RGGI Impact on LMP (No Border Adjustment)



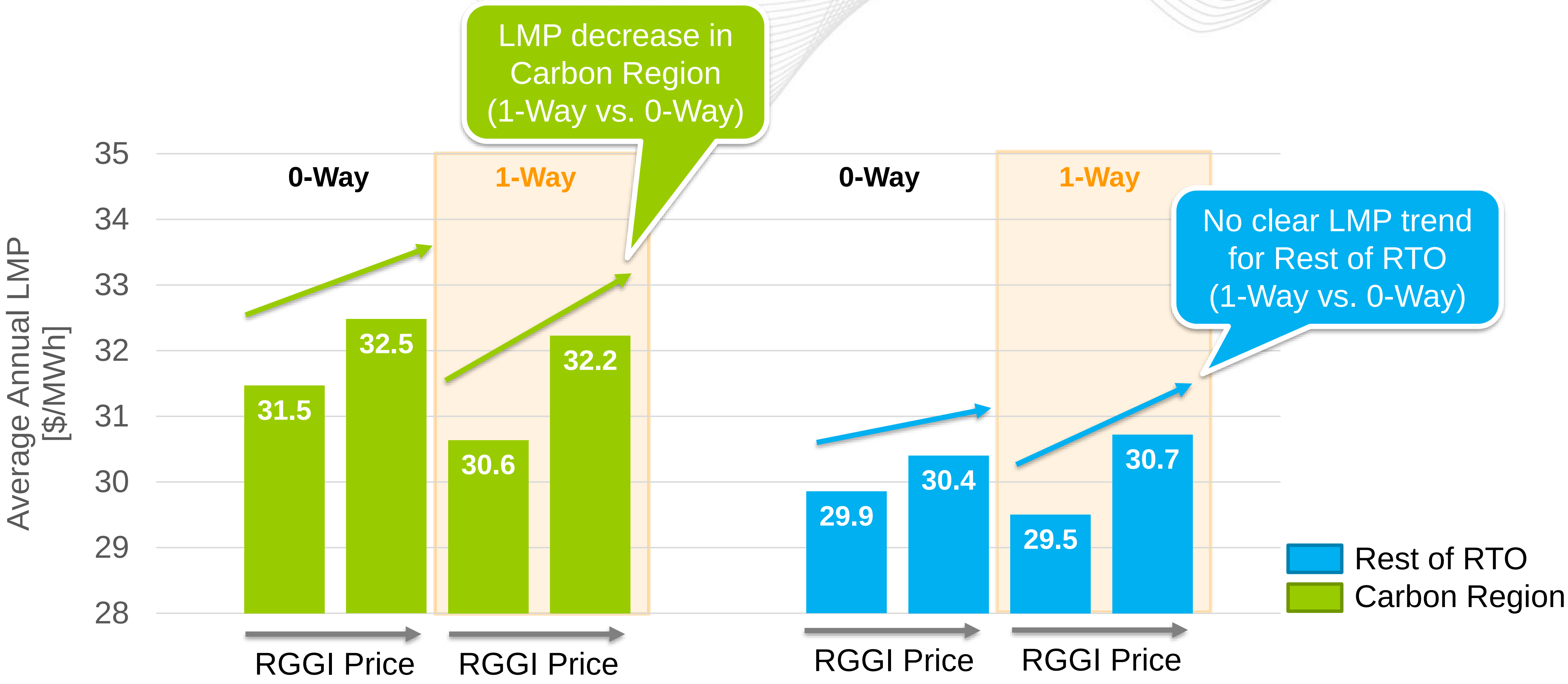
Under the Hood



Border Adjustment Mitigation - Emissions



Border Adjustment Mitigation – Impact on LMP



Executive Summary Observations

- At relatively low RGGI prices, emissions leakage is in the order of [0.5%, 1.7%].
- Net RTO emissions and impact on LMP increase with RGGI price.
- Border adjustment:
  - Mitigates emissions leakage.
  - Mitigates the impact on LMP.
  - Increases emissions within the Carbon region.

NOT General Conclusions
(Do NOT extrapolate)

Strong function of:

- States in the carbon region.
- Generation fleet.
- Carbon price (non-linear).

Executive Summary

Context, Objectives, and Study Assumptions

Results Part 1: Impacts of a RGGI Carbon Price in the PJM Energy Market

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

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

- Today: Review objectives and updated assumptions taking into account stakeholder feedback for the PJM Carbon Study

Objectives of Analysis

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 this **initial 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.

Review of Leakage Concepts

- Broadly defined, leakage refers to 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]

[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

Context for Leakage Mitigation in Study

There are multiple approaches to leakage mitigation:

- *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

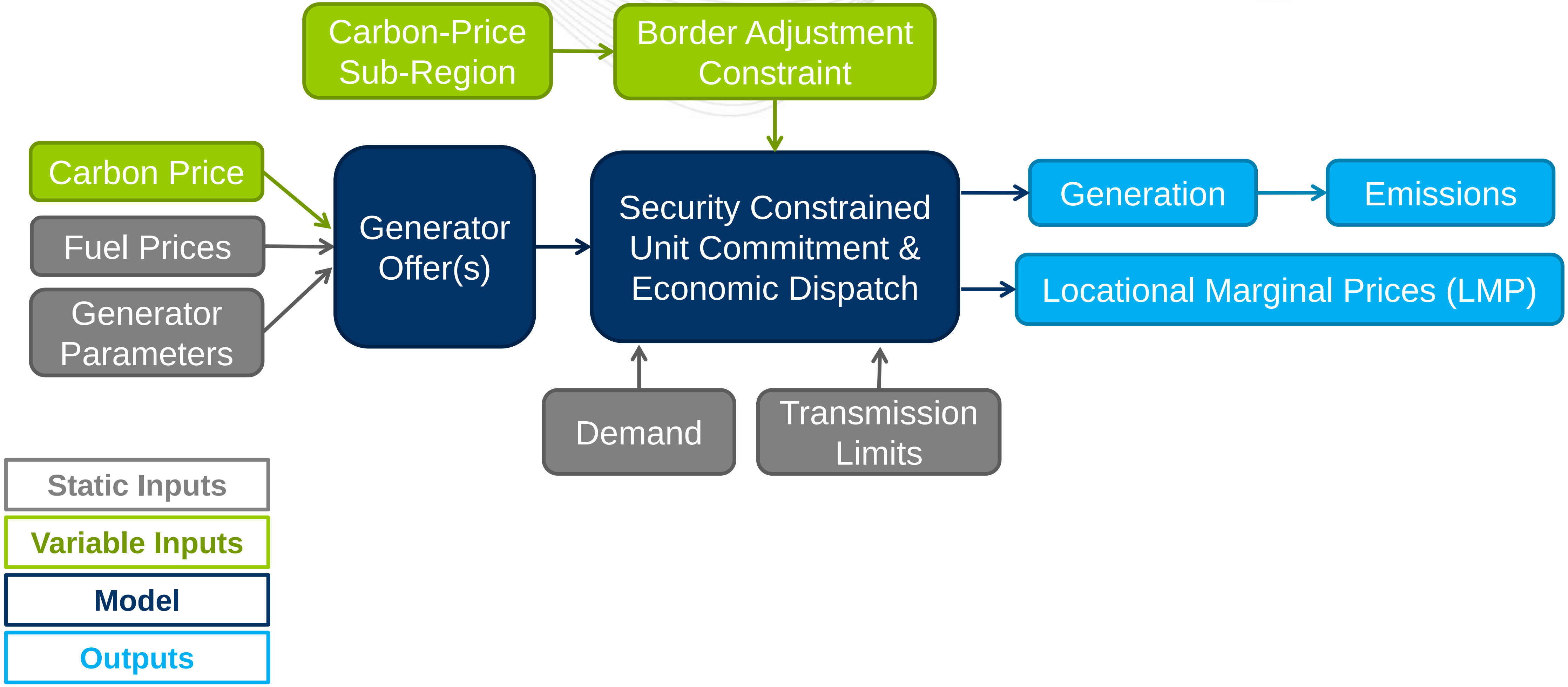
- *In study:* Border adjustment constraints within wholesale electricity market
  - One-way (transfers into carbon region)
  - Two-way (transfers into and out of carbon region)

Study Methodology

- Evaluate the impacts of a carbon price and potential leakage mitigation mechanisms on the PJM energy market by simulating the commitment and dispatch of resources, and the resulting market and emissions outcomes:
  - Utilized PLEXOS, a production cost modeling tool that performs security constrained unit commitment and economic dispatch over a given time horizon & granularity.
    - Provided flexibility needed to model system complexities while developing custom constraints for simulating border adjustments for leakage mitigation.
  - Current phase will model **2023** (most recent planning case from Regional Transmission Expansion Plan and Market Efficiency process)
  - Future analysis may include longer-term modeling to evaluate potential changes to resource mix from application of a carbon price – *out of scope for current phase*.

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

Study Methodology: Modeling Overview



Study Variables

- Carbon Price
- Carbon-Price Sub-Region
- Border Adjustment Approaches

Study Variables: **Carbon Price**

Assumed carbon price in PJM comes from Regional Greenhouse Gas Initiative (RGGI), and was modeled at \$6.87/short ton of CO_2 as a low-end reference and \$14.88/short ton of CO_2 as a high-end reference.

- \$6.87/short ton is the trigger price for the RGGI Emissions Containment Reserve (ECR) in 2023. \$14.88/short ton is the trigger price for the RGGI Cost Containment Reserve (CCR) in 2023. [1]

Carbon price is applied to the offers of resources that meet the RGGI program's "CO_2 Budget Source" definition.

- A "CO_2 Budget Source" under RGGI is a fossil-fuel-fired electric power generator with a capacity of 25 MW or greater within a RGGI state. [1]
- When a border adjustment is simulated, this definition is extended to resources in other states for making available an offer that includes the carbon price.

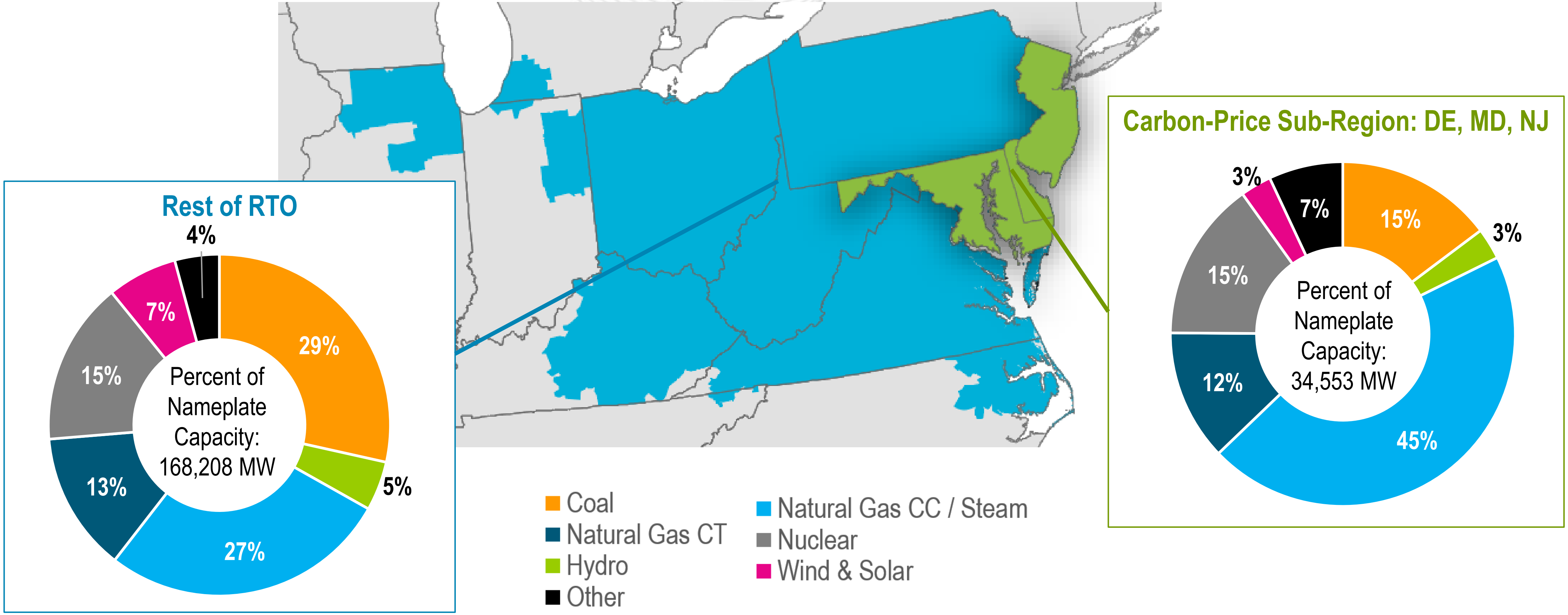
[1] RGGI 2017 Model Rule, https://www.rggi.org/sites/default/files/Uploads/Design-Archive/Model-Rule/2017-Program-Review-Update/2017_Model_Rule_revised.pdf

Study Variables: **Carbon-Price Sub-Region Definition**

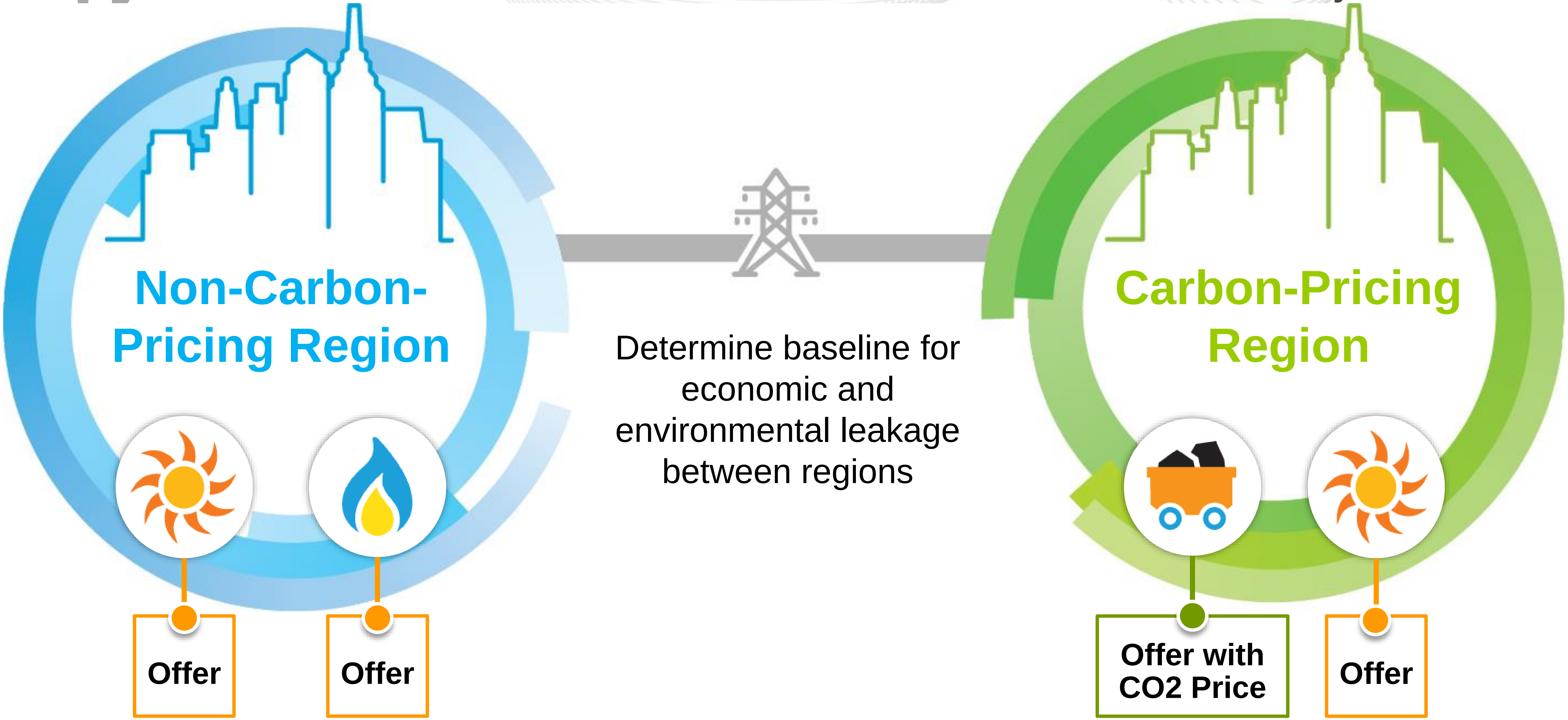
- The current set of results consider PJM states currently participating in RGGI (DE, MD, NJ) as part of the carbon-price sub-region.
  - Note: New York is modeled with a carbon price, as it is a RGGI state. Study results are focused on the PJM RTO.

Study Variables: **Carbon-Price Sub-Region Definition**

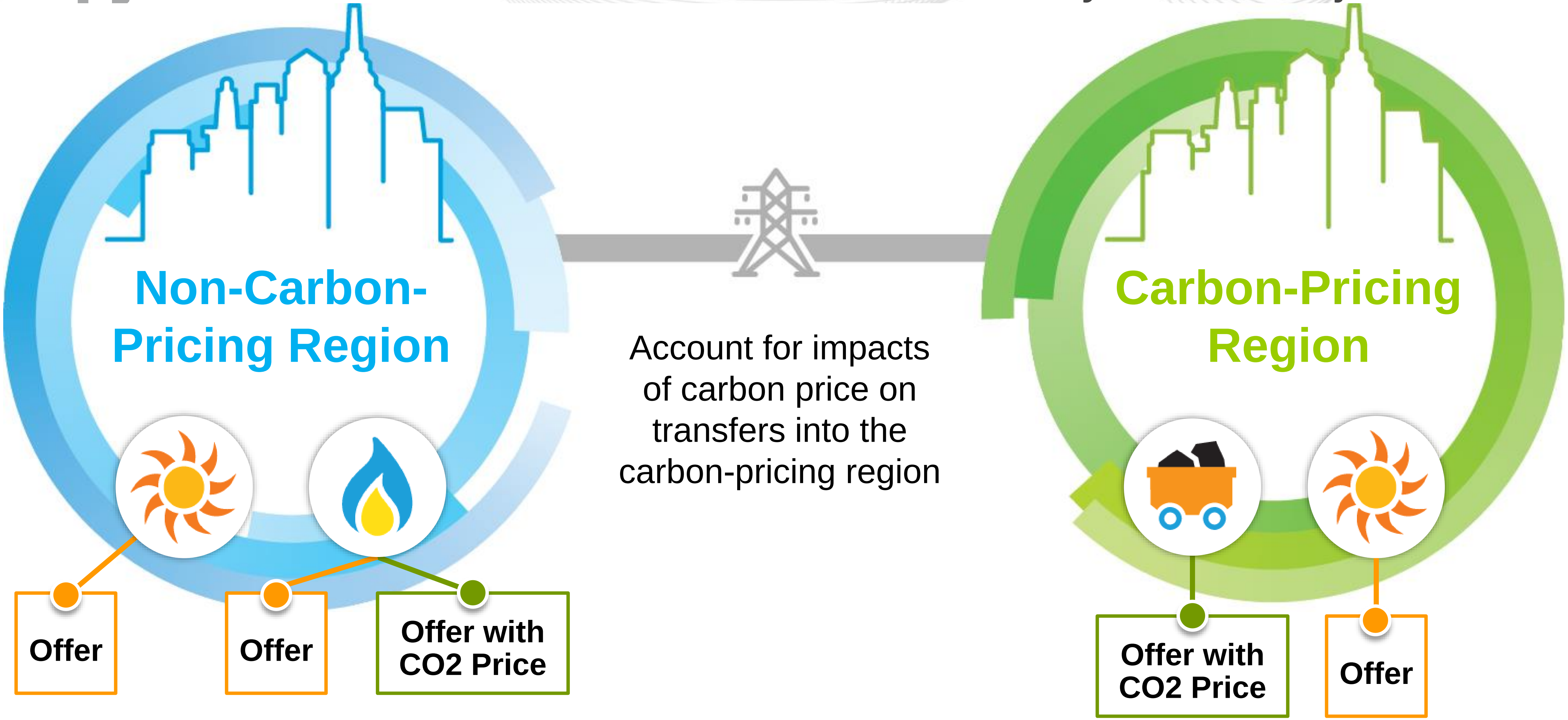
Results depend on the generation mix, and emissions intensities, of each sub-region.



No Border Adjustment



One-Way Border Adjustment

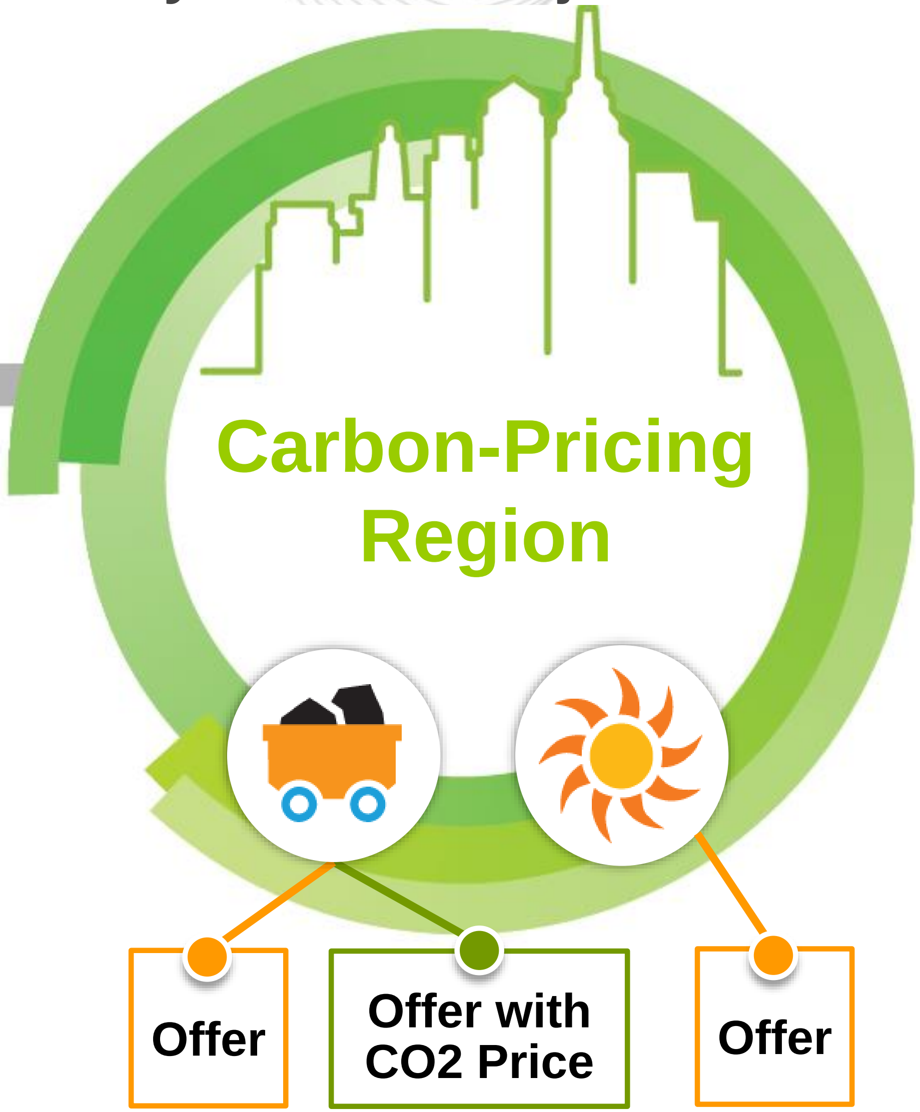


Account for impacts of carbon price on transfers into the carbon-pricing region

Study Variables: Border Adjustment Approaches

Two-Way Border Adjustment

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



Carbon Revenue – RGGI Revenue

- 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.

Carbon Revenue – Residual Funds

- 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.

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Part 1 Scenario Summary

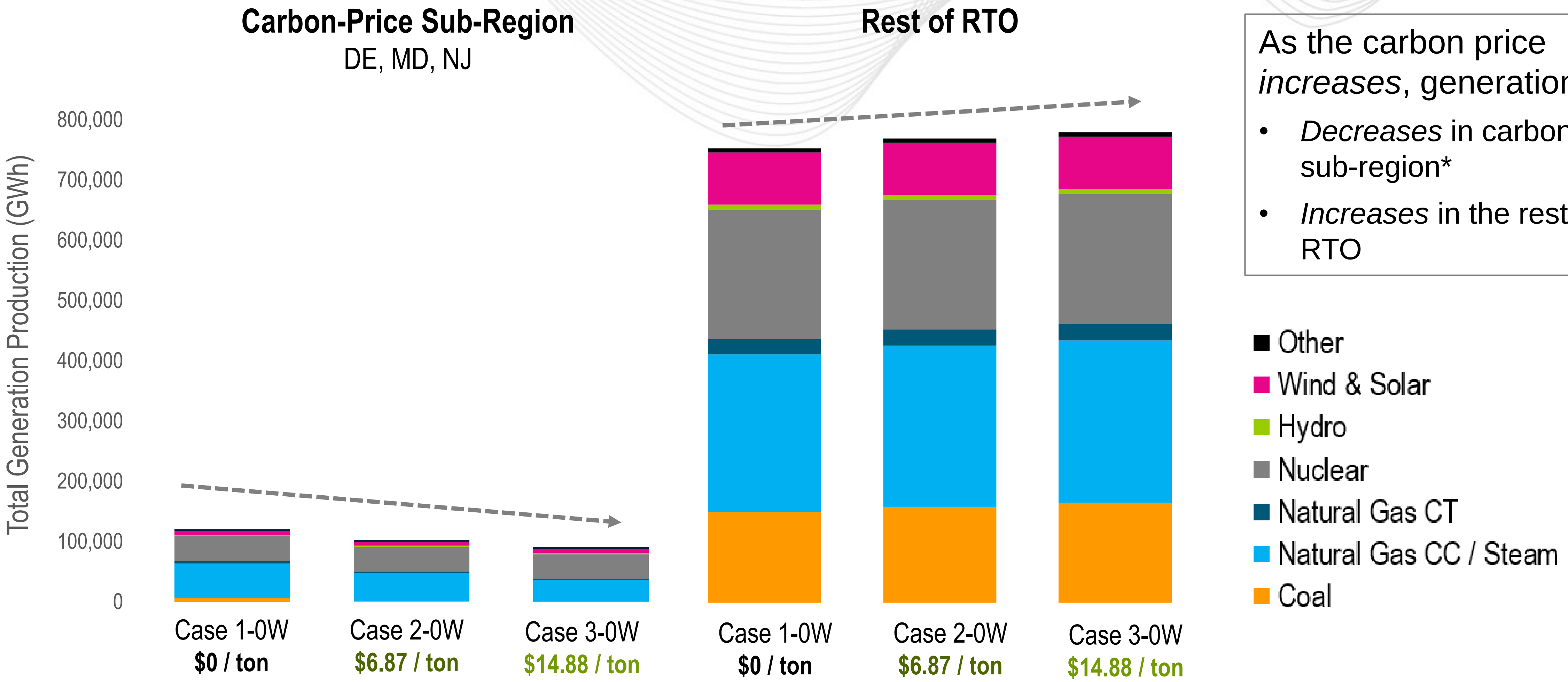
Impacts Associated with a RGGI Carbon Price in the PJM Energy Market

- 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 2-0W	$6.87/short ton	None
Case 3-0W	$14.88/short ton	None

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

2023 Generation Production by Sub-Region

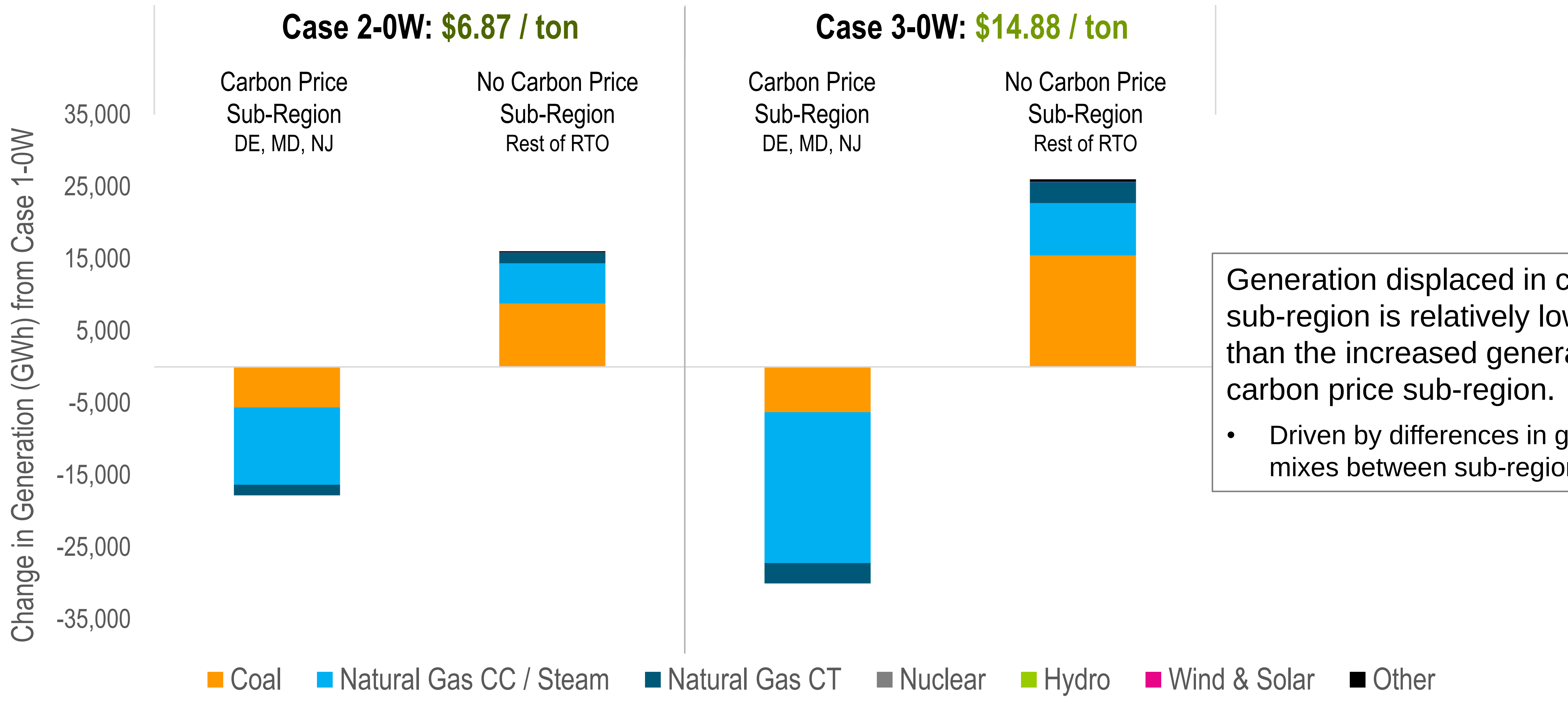


As the carbon price *increases*, generation:

- *Decreases* in carbon-price sub-region*
- *Increases* in the rest of the RTO

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

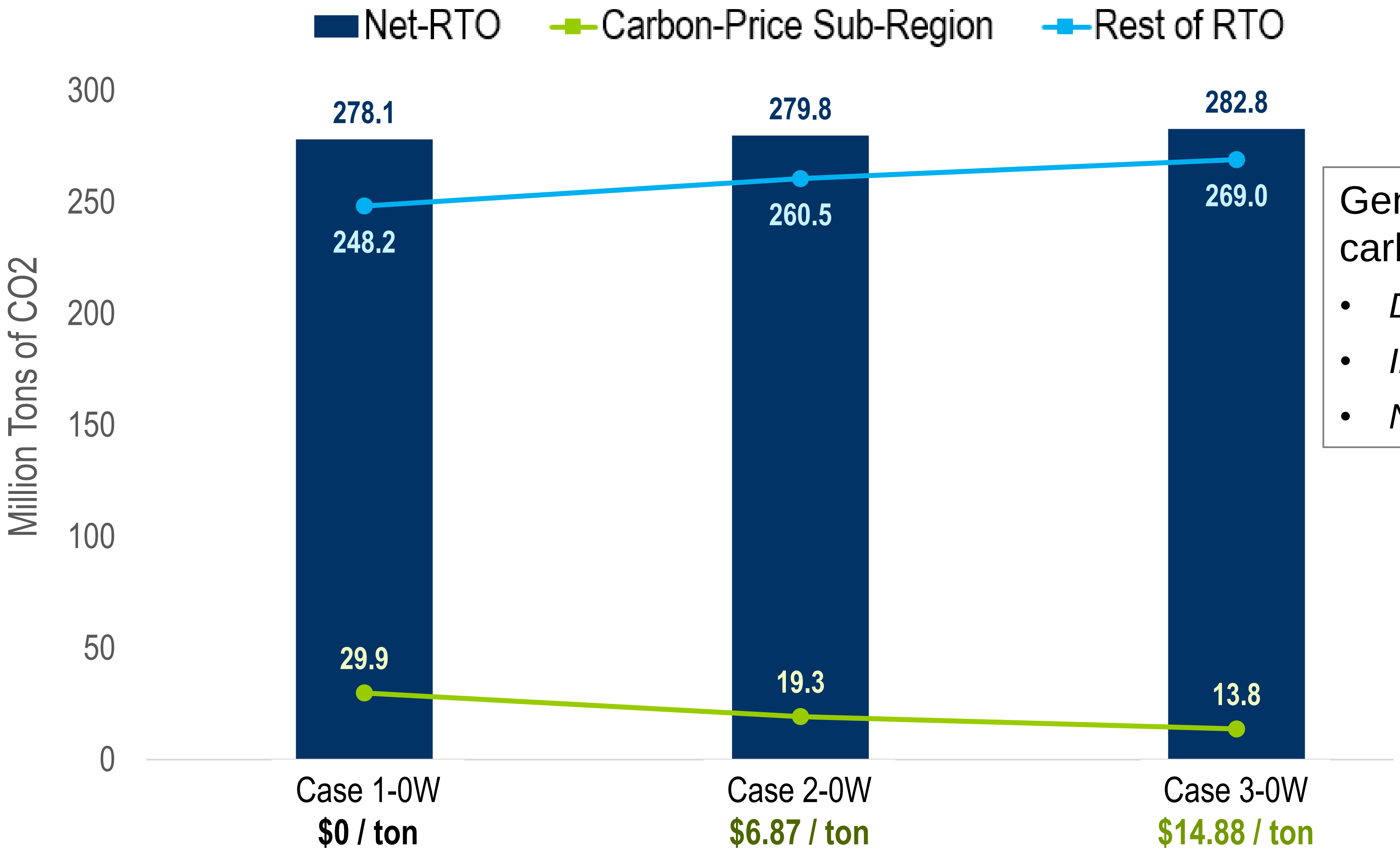
2023 Shifts in Generation Production from Case 1 ($0 / ton CO_2) by Sub-Region



Generation displaced in carbon-price sub-region is relatively lower-emitting than the increased generation in no carbon price sub-region.

- Driven by differences in generation mixes between sub-regions.

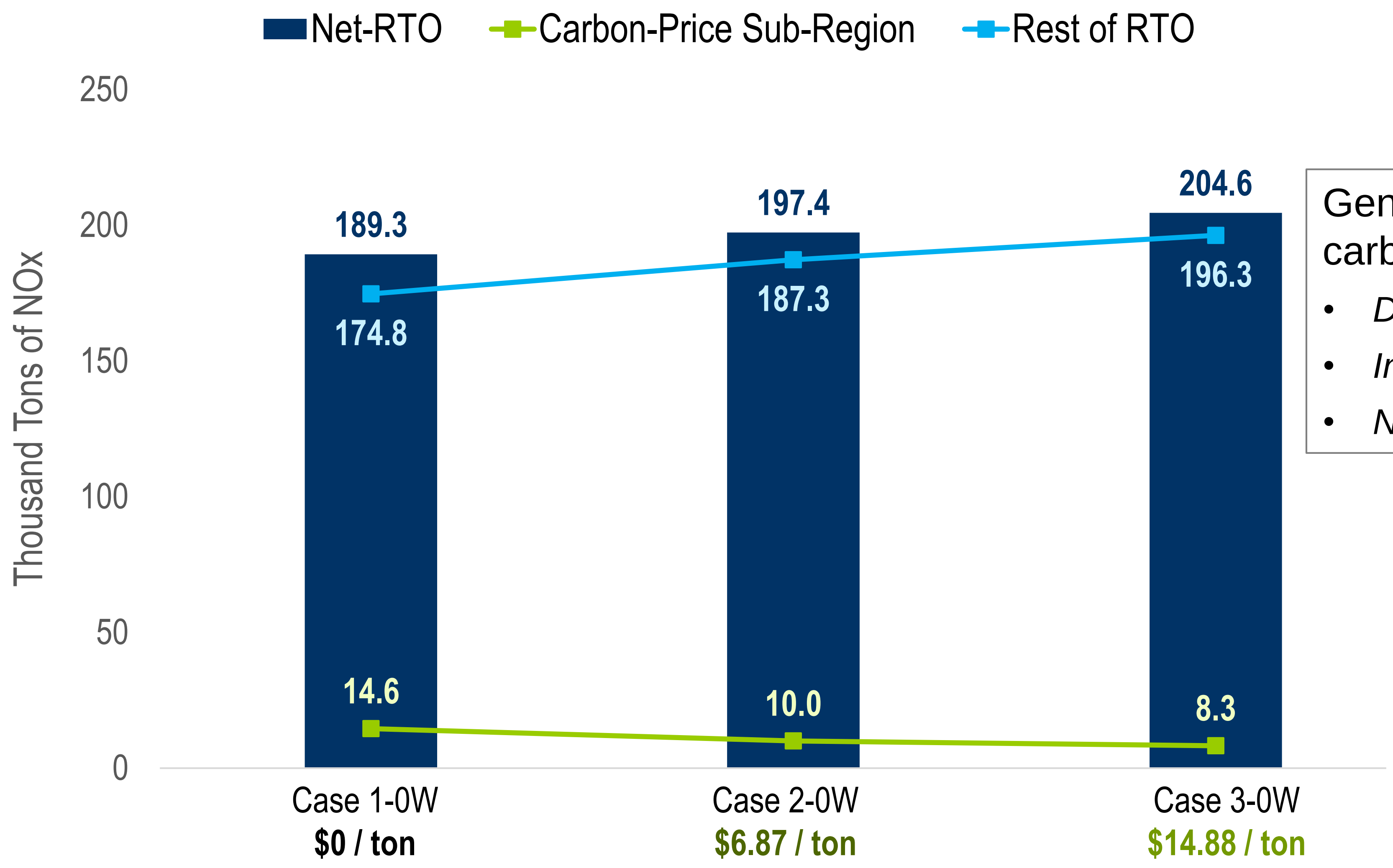
2023 Total CO_2 Emissions



Generation shift from increasing carbon price results in CO_2:

- *Decrease* in carbon-price sub-region
- *Increase* in no carbon-price sub-region
- *Net increase* across RTO

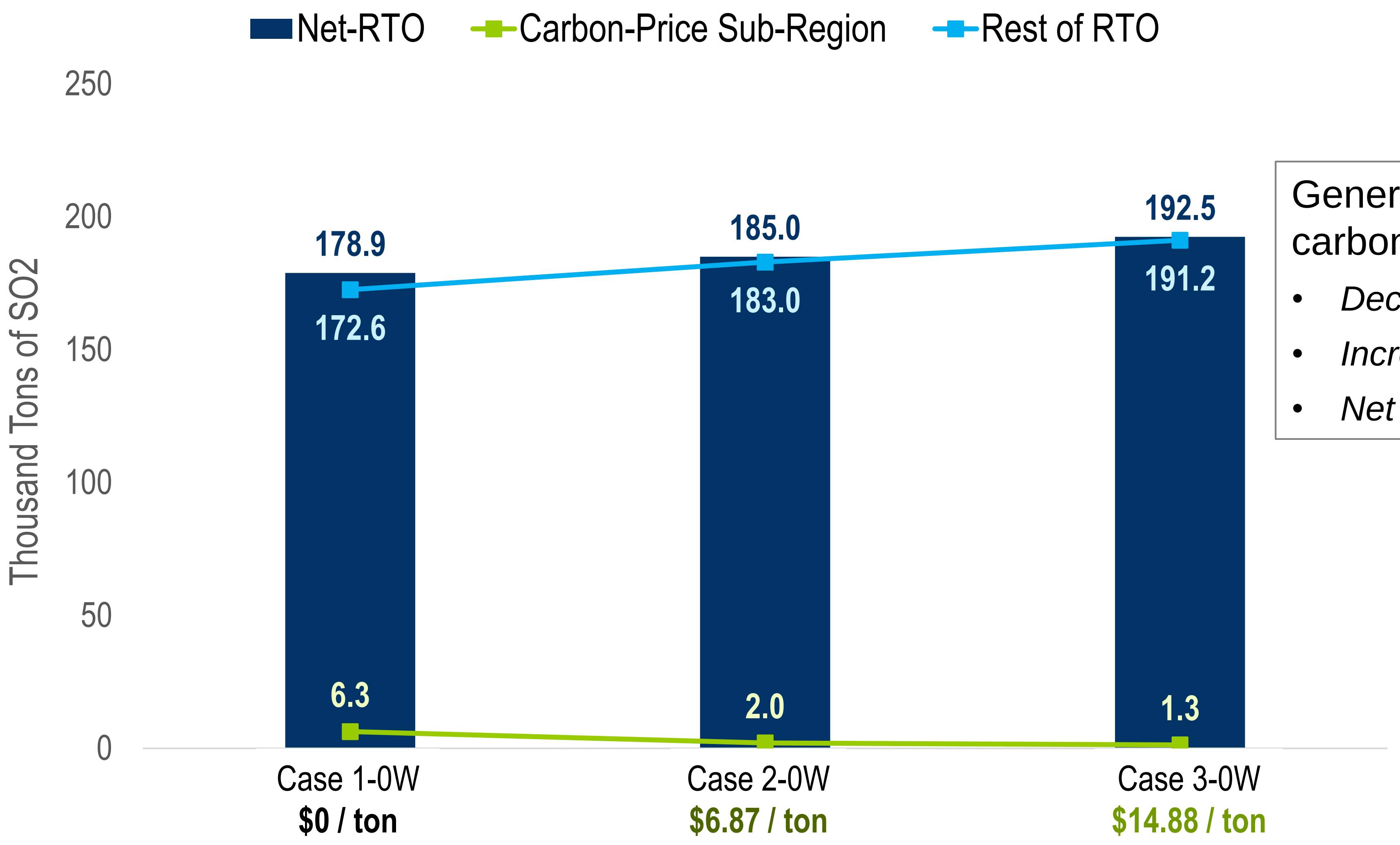
2023 Total NO_X Emissions



Generation shift from increasing carbon price results in NO_X:

- *Decrease* in carbon-price sub-region
- *Increase* in no carbon-price sub-region
- *Net increase* across RTO

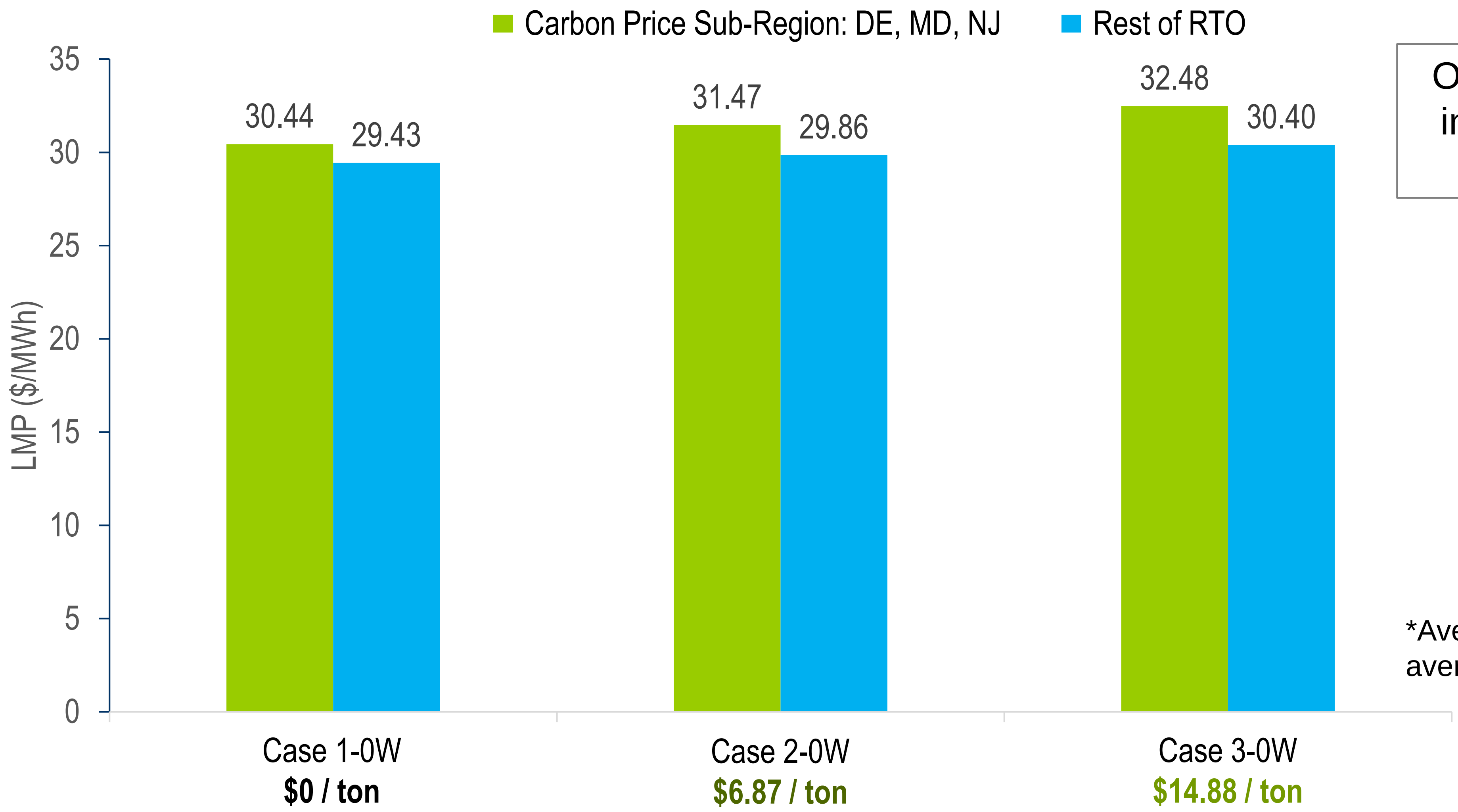
2023 Total SO_2 Emissions



Generation shift from increasing carbon price results in SO_2:

- *Decrease* in carbon-price sub-region
- *Increase* in no carbon-price sub-region
- *Net increase* across RTO

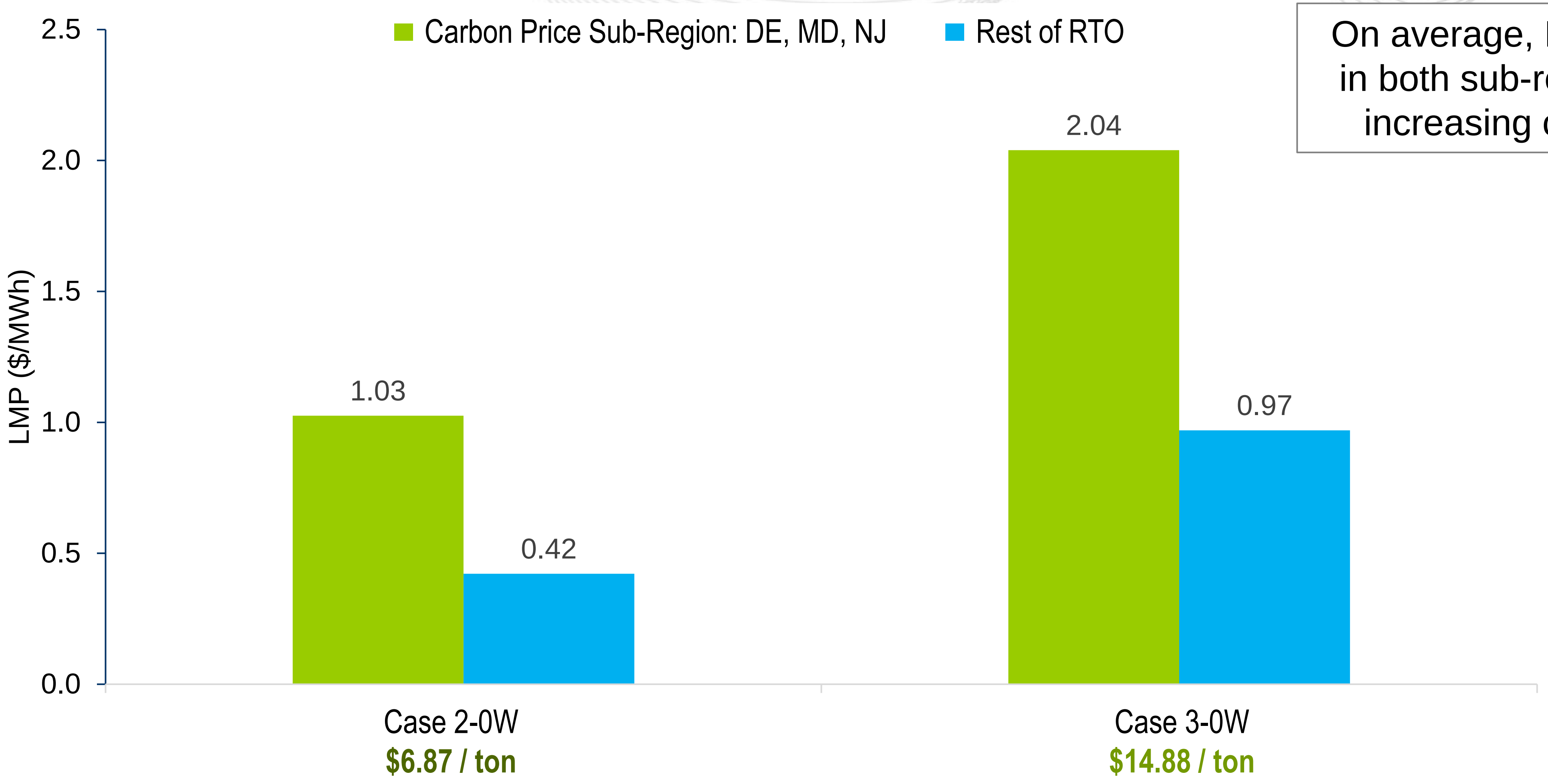
2023 PJM Average Yearly LMPs* by Sub-Region & Carbon Price



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 by Sub-Region & Carbon Price



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

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

	Generation		Emissions		LMP	
Case 1-0W ($0 / ton)	—	—	—	—	—	—
Case 2-0W ($6.87 / ton)	↓	↑	↓	↑	↑	↑
Case 3-0W ($14.88 / ton)	↓	↑	↓	↑	↑	↑

■ Carbon Price Sub-Region: DE, MD, NJ ■ 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 a relatively lower emissions intensity than the increased generation in the Rest of RTO. This is driven by the differences in generation mix between the two sub-regions.

- **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 increase 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.

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

Leakage Mitigation Mechanism: Border Adjustments

- 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.

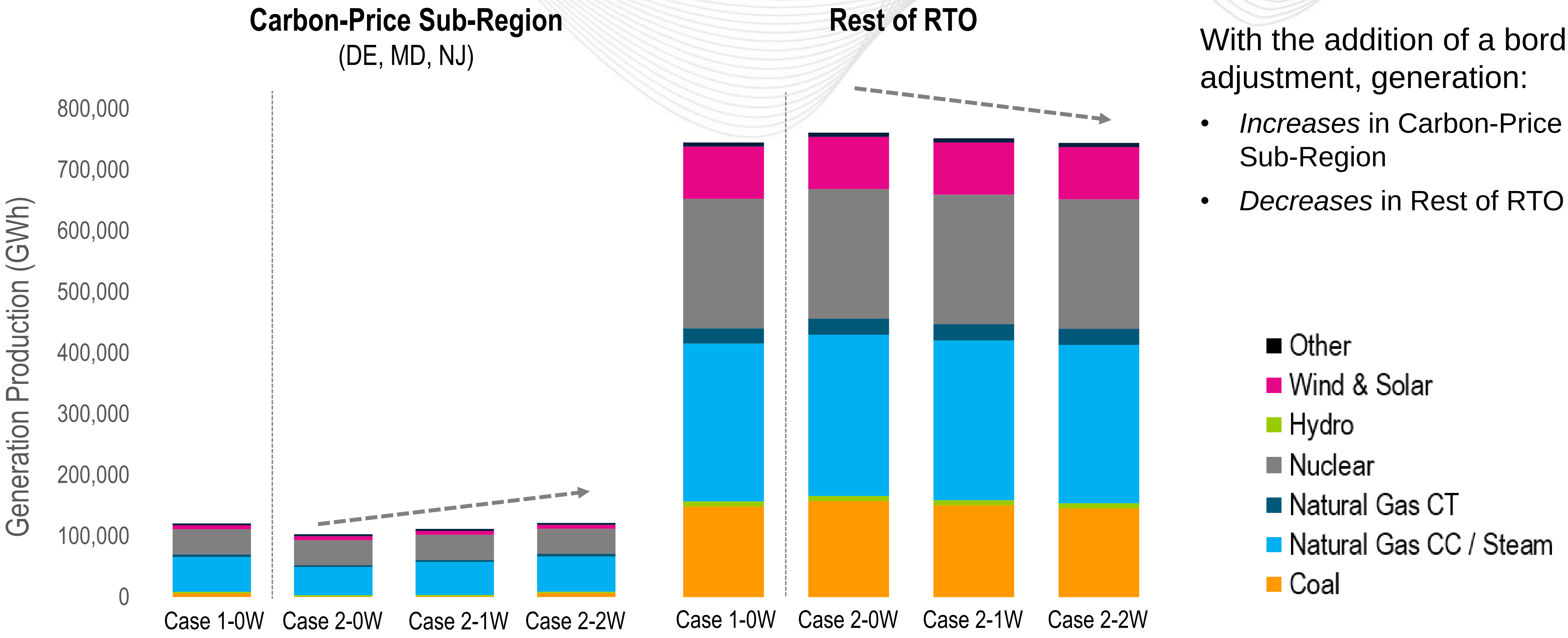
- The year 2023 was simulated for the following cases:

Case	RGGI Price	Border Adjustment
Case 2-0W	$6.87/short ton	None
Case 2-1W	$6.87/short ton	One-Way
Case 2-2W	$6.87/short ton	Two-Way
Case 3-0W	$14.88/short ton	None
Case 3-1W	$14.88/short ton	One-Way
Case 3-2W	$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 and NJ
  - Rest of RTO – all other states in PJM

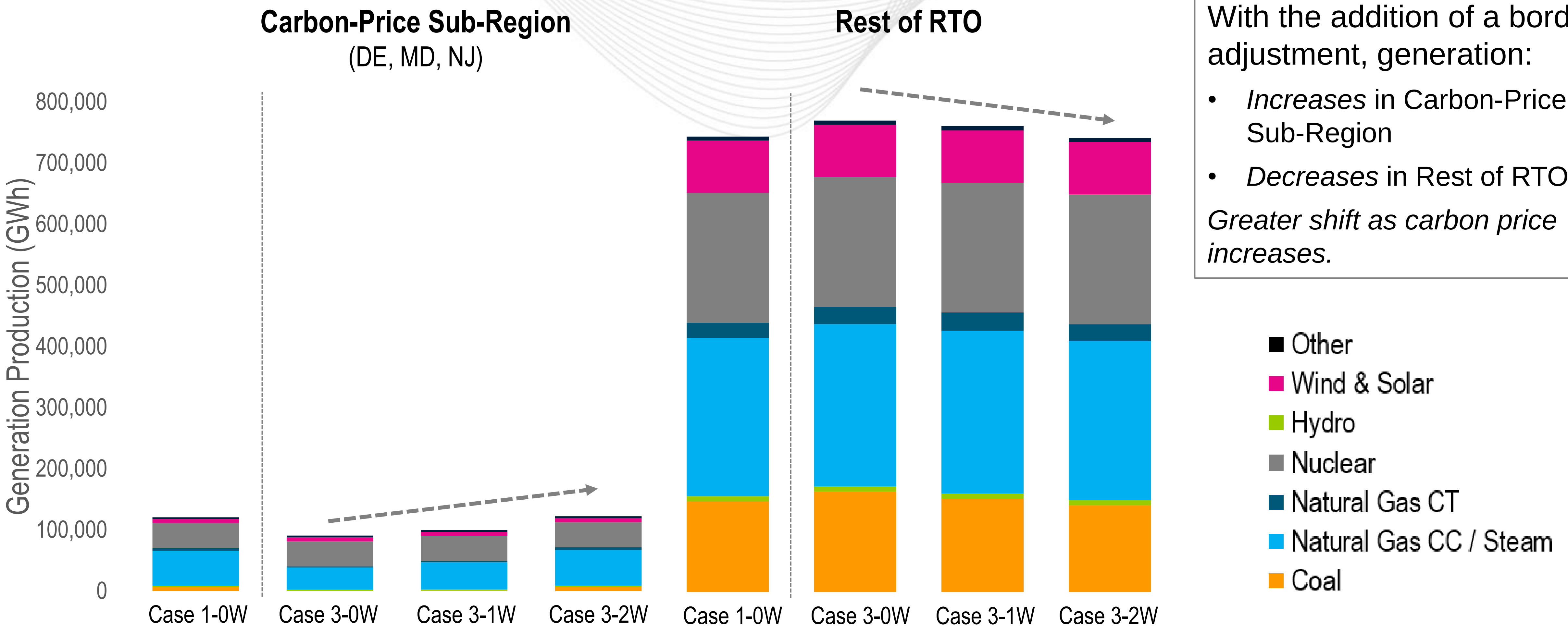
2023 Generation Production by Sub-Region: **$6.87 / ton CO_2**



With the addition of a border adjustment, generation:

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

2023 Generation Production by Sub-Region: **$14.88 / ton CO_2**

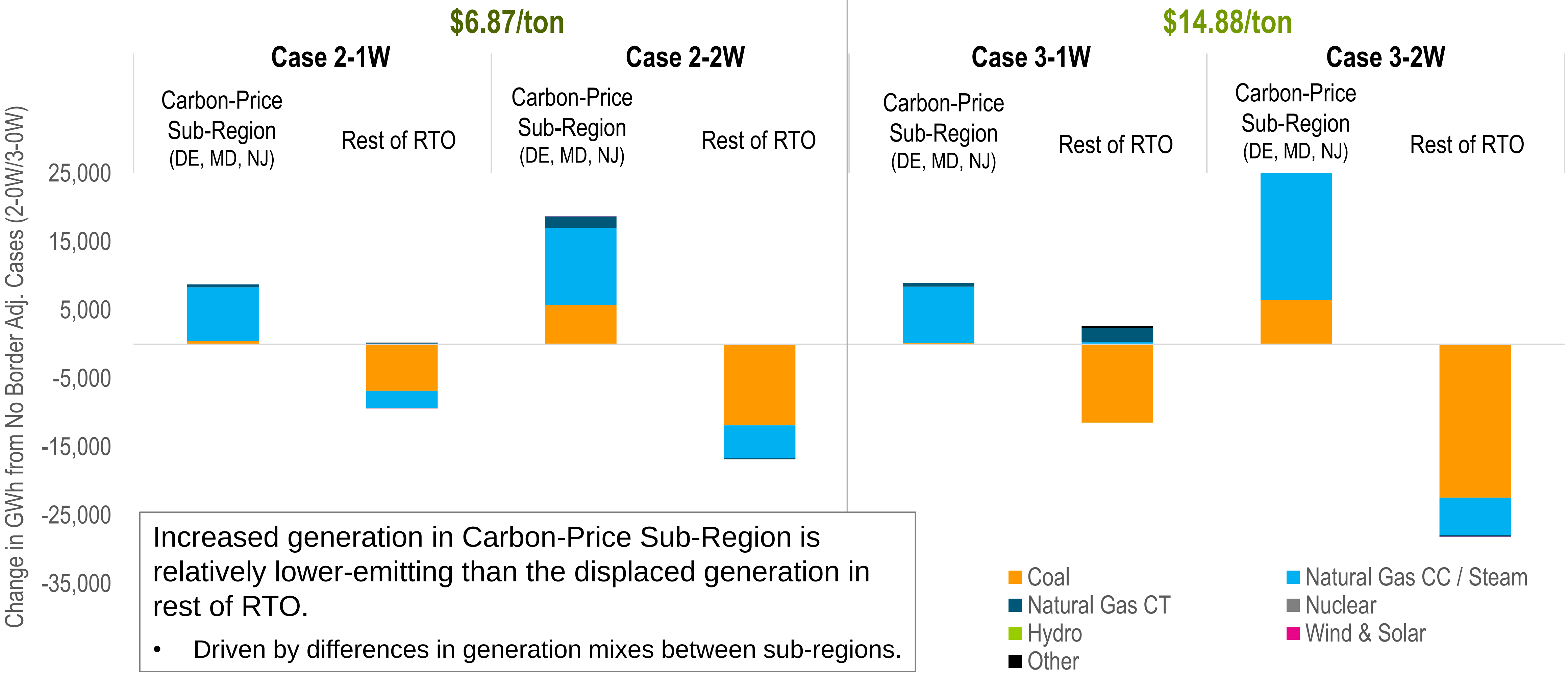


With the addition of a border adjustment, generation:

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

Greater shift as carbon price increases.

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

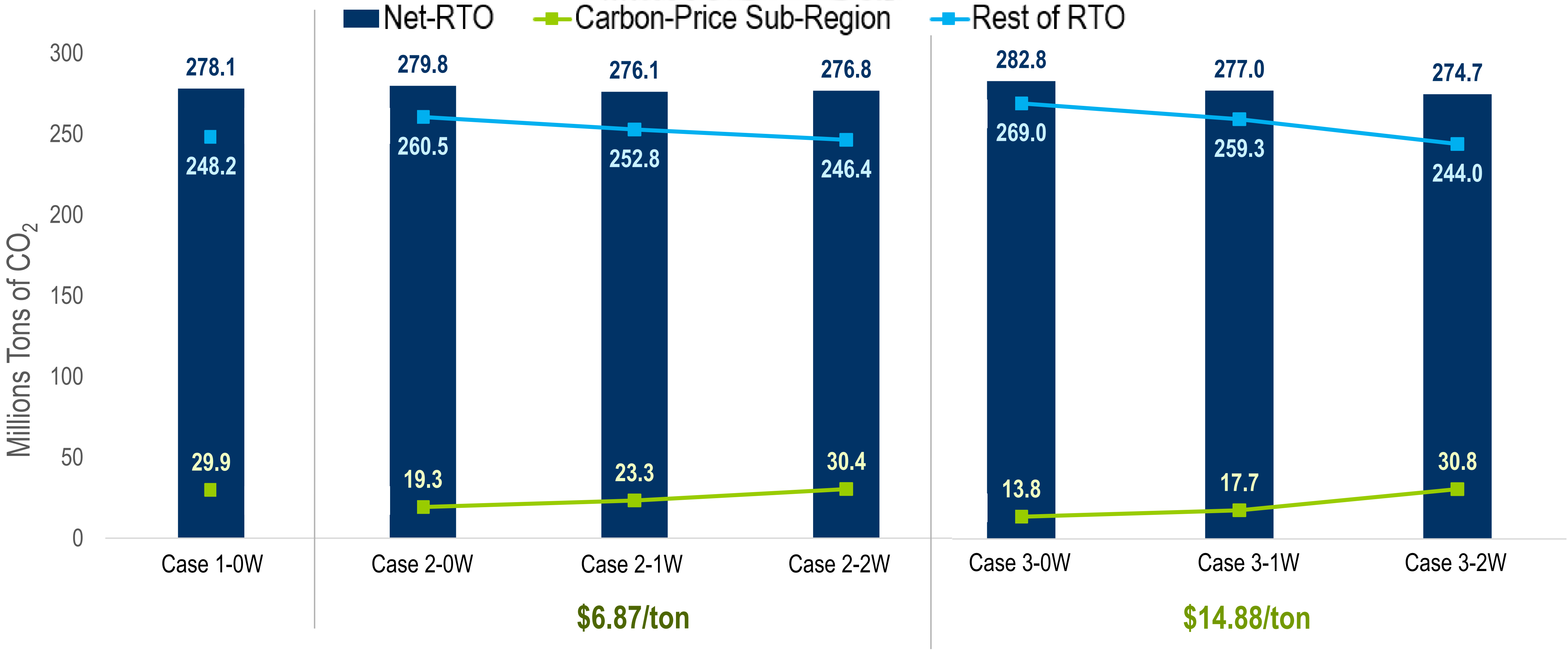


Increased generation in Carbon-Price Sub-Region is relatively lower-emitting than the displaced generation in rest of RTO.

- Driven by differences in generation mixes between sub-regions.

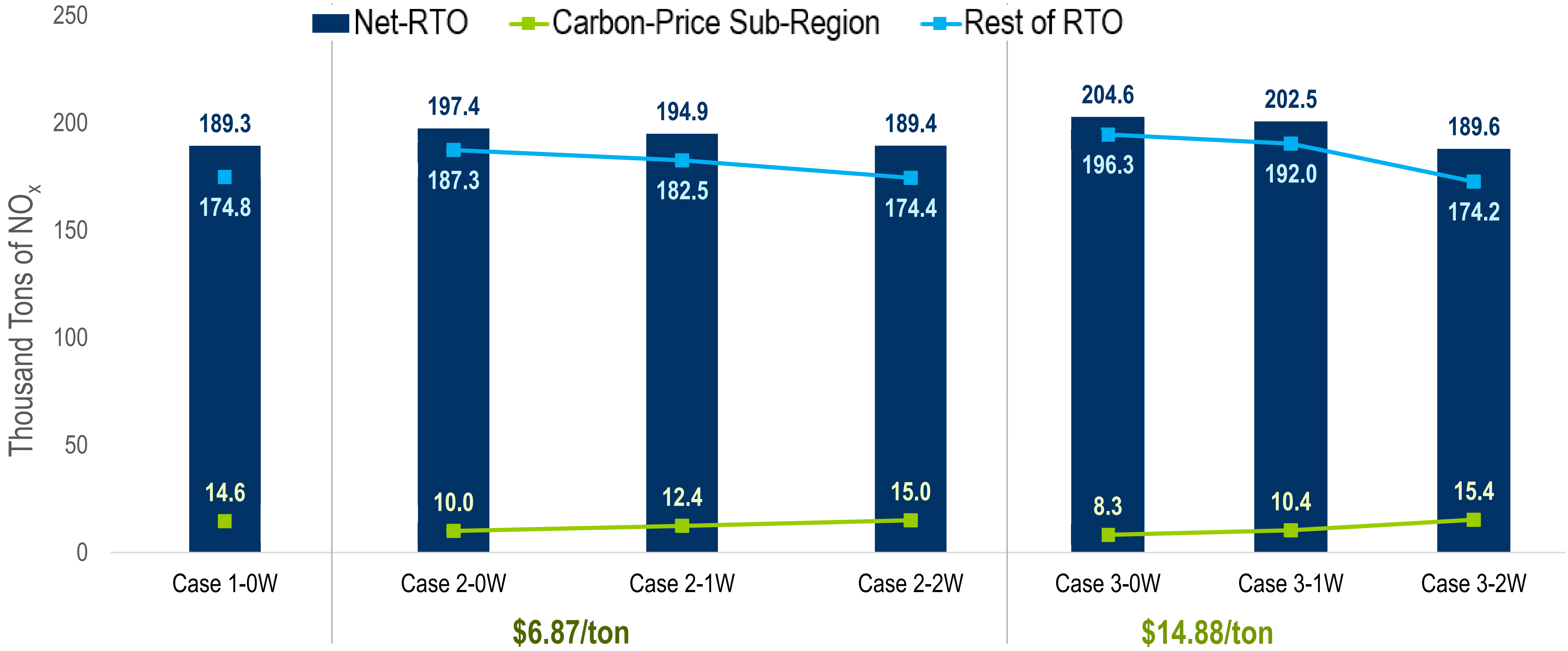
Impact of Border Adjustment on CO_2 Emissions

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.



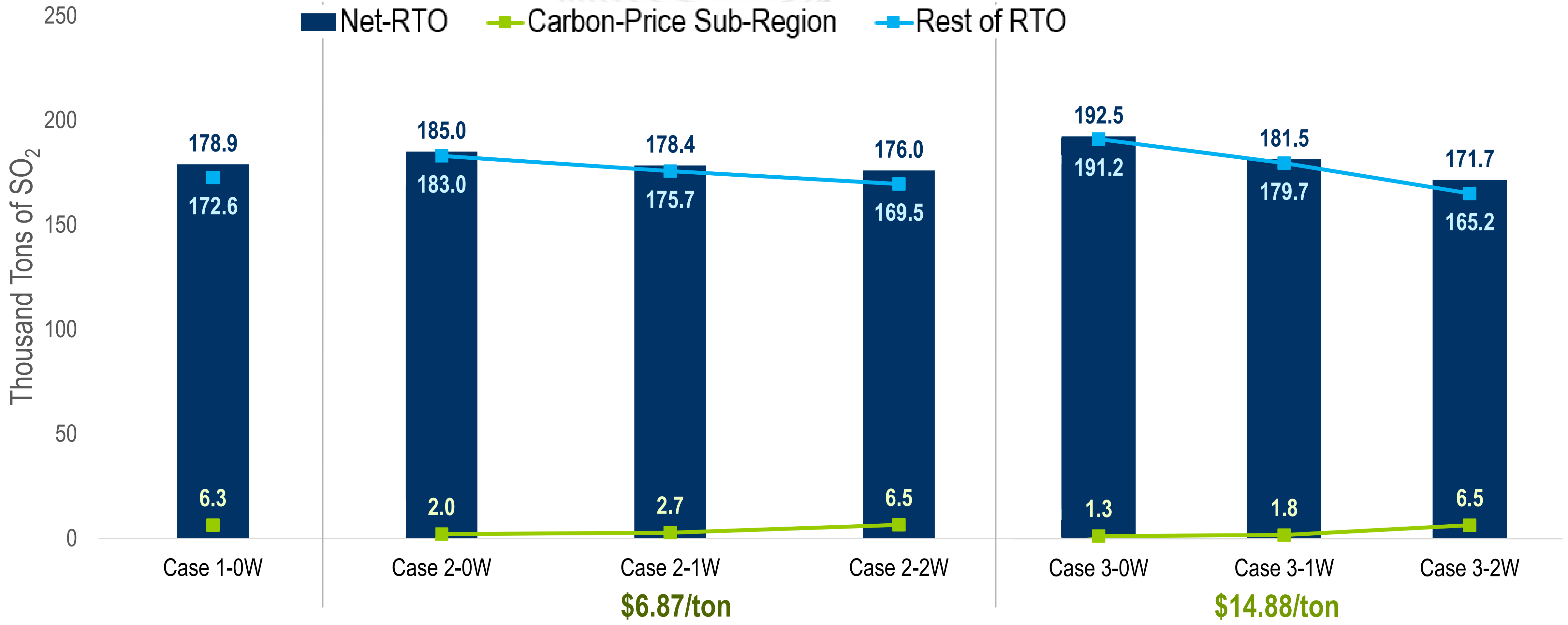
Impact of Border Adjustment on NO_X Emissions

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.

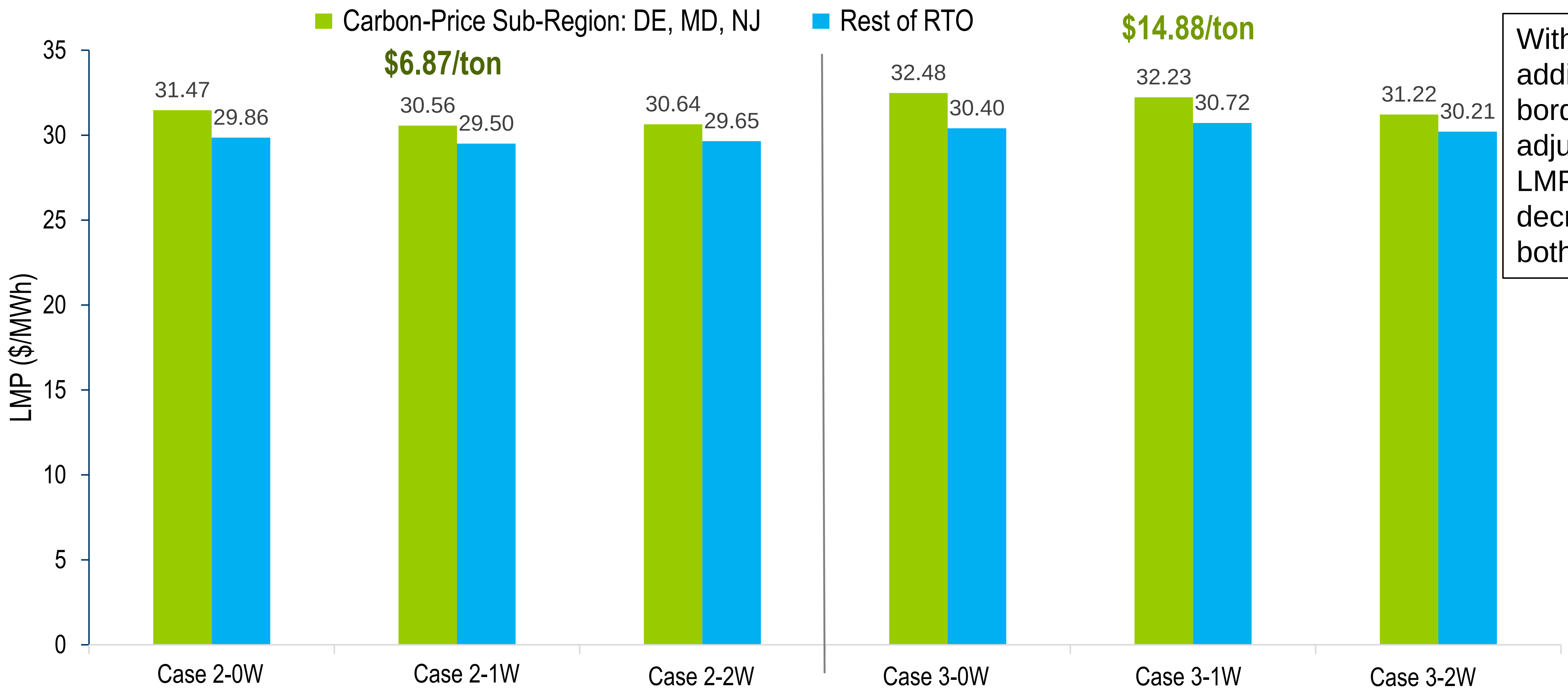


Impact of Border Adjustment on SO_2 Emissions

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.



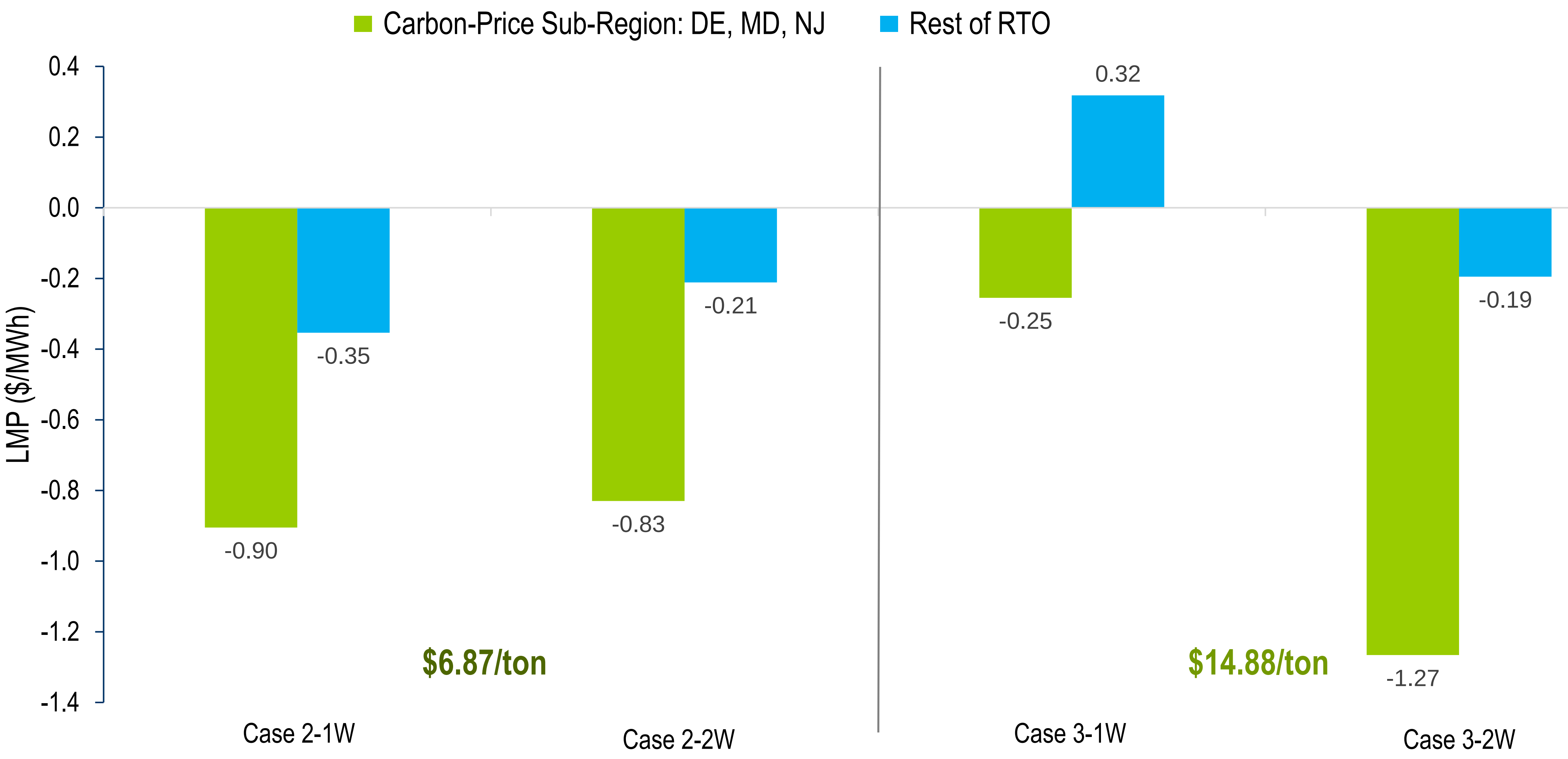
2023 PJM Average Yearly LMPs* by Sub-Region



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



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

Impact of Border Adjustment on CO_2 Emission Costs to Generators

- 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 CO_2 allowance sales that states would collect if the CO_2 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.

Results Summary

Part 2: Impacts of Potential Border Adjustments for Leakage Mitigation

	Generation	Emissions	LMP
Case 2-0W ($6.87 / ton)	— —	— —	— —
Case 2-1W ($6.87 / ton)	↑ ↓	↑ ↓	↓ ↓
Case 2-2W ($6.87 / ton)	↑ ↓	↑ ↓	↓ ↓
Case 3-0W ($14.88 / ton)	— —	— —	— —
Case 3-1W ($14.88 / ton)	↑ ↓	↑ ↓	↓ ↑
Case 3-2W ($14.88 / ton)	↑ ↓	↑ ↓	↓ ↓

■ Carbon Price Sub-Region: DE, MD, NJ ■ 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. This is reflective of the differences in generation mix between the two sub-regions.

- **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.
  - The change in emissions are 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.