System Dynamics Analysis on the Rising Prices of RGGI Emissions Allowances in the U.S. Northeast Auctions

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Abstract

The Regional Greenhouse Gas Initiative (RGGI) is a cap-and-trade program for CO_2 emissions from the power sector in the Northeastern United States. It has recently experienced a notable rise in auction clearing prices, historical high $26.73 per short ton in December 2025. This spike represents a 771% surge relative to that of late 2008, and the depletion of key market buffers underscores emerging dynamics in allowance supply, demand, and policy design. This paper employs systems thinking approach to describe the causal relationships and feedback loops governing the RGGI's price behavior. Key structural elements in the model include emissions cap, auction supply schedules, and the Cost Containment Reserve (CCR) mechanisms designed to moderate price spikes on the RGGI supply side. The model also illustrates, on the demand side, the role of external factors such as compliance cycle, policy credibility, and speculative demand, as well as regional fuel costs and broader decarbonization policies that affect and may be affected by upward price pressures. The findings provide insights into the nonlinear mechanisms that surround allowance price formation and volatility within RGGI's market architecture. These results offer policy implications for emissions trading systems worldwide, especially in designing adaptive containment tools, calibrating emissions cap, and anticipating dynamic market responses to regulatory shifts. The study contributes to a deeper understanding of carbon market dynamics and offers guidance for improving future carbon pricing designs under conditions of increasing climate ambition.

Keywords

RGGI allowances, RGGI price, CO_2 emissions market, Systems thinking, Clean energy policy.

1. Introduction

Regional Greenhouse Gas Initiative (RGGI) is the first multi-state cap-and-trade program in the U.S. New England and the Mid-Atlantic States aimed at reducing carbon dioxide (CO_2) emissions from the power sector with a generating capacity of 25 MWs or greater. Starting with seven founding states in 2005, RGGI currently includes ten participating states: Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont. Since the first auction in September 2008, RGGI has conducted seventy quarterly auctions as of December 2025. In the latest Auction 70, 15.23 million of emissions allowances were sold at a clearing price of $26.73 per short ton of CO_2, generating approximately $407 million in proceeds [1].

RGGI operates through a declining regional emissions cap implemented by issuing tradable CO_2 allowances, each representing authorization to emit one short ton of CO_2. Regulated power plants are required to hold and surrender allowances equal to their verified emissions over multi-year compliance periods. Allowances are distributed primarily through region-wide auctions and may be freely traded and banked, allowing market participants to manage compliance costs over time [2].

The annual regional emissions cap was significantly reduced following the 2012 Program Review, with the 2014 cap set at 91 million short tons, which compares to 188 million allowances in 2009-2011 period, and declining annually by 2.5% through 2020 [3, 4]. Over time, the cap trajectory has been further adjusted through subsequent program reviews to align with deeper decarbonization goals. By 2020, power-sector CO_2 emissions in RGGI states had declined to approximately seventy-seven million short tons, representing a 46% reduction from the 2006–2008 baseline average of 142 million short tons.

After the initial agreement in 2005, RGGI established its foundational regulatory framework through 2006, or cost-management mechanisms. A Cost Containment Reserve (CCR) releases additional allowances into the market when auction clearing prices exceed predefined trigger levels, increasing short-term supply during periods of high demand. Under the 2013 Model Rule revisions, the CCR included an annual withdrawal limit of 5 million allowances in 2014 and 10 million allowances in subsequent years, with trigger prices initially set at \$4 (2014), \$6 (2015), \$8 (2016), and \$10 (2017), increasing by 2.5% annually thereafter [3]**.** In addition, Emissions Containment Reserve (ECR), a minimum reserve price at auction, establishes a price floor below which allowances will not be sold, preventing prices from falling to levels that could undermine emissions reduction incentives.

The 2025 review of the model introduced updates that strengthen the regional CO_2 emissions cap from 2027 through 2037, while expanding mechanisms to protect energy affordability. The annual regional cap is reduced to approximately 69.8 million tons in 2027, about six million tons lower than under the previous rule, followed by an average annual decline of about 10.5% through 2033 and a slower decline of roughly 3% per year through 2037. To address price volatility and grid reliability, the existing CCR is expanded into a two-tier structure, allowing additional allowances to be released at progressively higher trigger prices. The ECR is eliminated and replaced with an increased minimum reserve price, set at \$9.00 in 2027 and rising by 7% annually [5].

Proceeds from RGGI emissions allowance auctions are returned to participating states and reinvested in energy and consumer benefit programs. In 2023, RGGI investments totaled approximately \$852 million, with the largest share allocated to energy efficiency programs (64%), reflecting an emphasis on reducing electricity demand and long-term energy costs. Direct bill assistance accounted for 15% of investments, providing immediate electricity cost relief, while clean and renewable energy programs received about 6%. When categorized by recipient type, residential efficiency and clean energy programs accounted for 59% of total funding, followed by municipal, state, and community programs (13%), low-income rate relief and efficiency programs (7%), and smaller shares directed to businesses, general rate relief, clean transportation, and research [6].

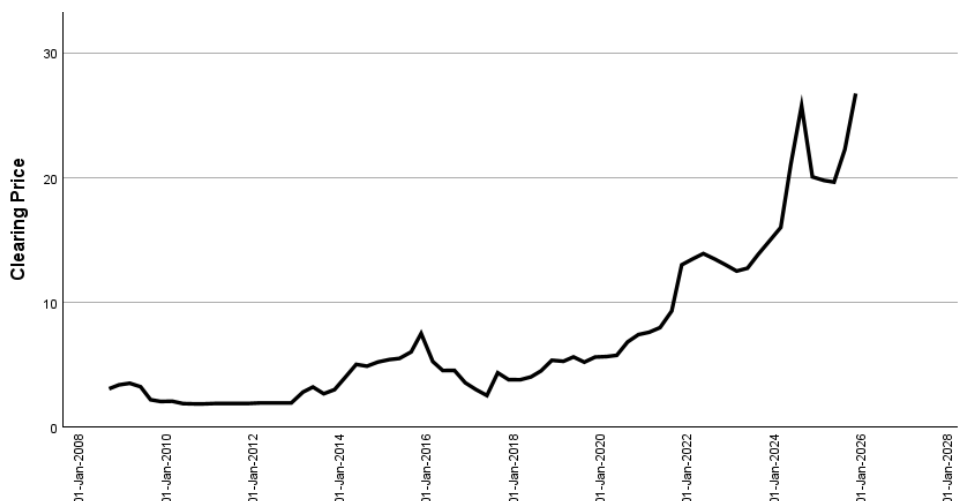

Figure 1. History of RGGI Clearing Prices in the Past 70 Auctions

While the RGGI program is designed to create carbon neutral initiatives by emissions cap setting, and promote investments in energy efficiency and R&D projects with the RGGI proceeds, the RGGI auction history reveals that the RGGI clearing prices have increased over the past seventy quarterly auctions. The success of the RGGI may be measured by the reduction of CO_2 in the participating states, but it is not deniable to anticipate that the higher RGGI prices will drive electricity producers to incorporate the RGGI prices in their electric prices at both the wholesale and retail markets. This will impose economic burdens on electricity consumers in the participating states. It is usually the management role and responsibility to cover a higher standard of living and stability of employment by incorporating the inflows of information, materials, manpower, and many capital equipment [7].

As shown in Figure 1, when the first RGGI Auction was held in September 2008, the RGGI clearing price was set at $3.07 per short ton of CO_2, and later skyrocketed 771% to $26.73 in Auction 70 in December 2025 [1]. The time series data of historical prices reveals that the price had stayed in a single digit until Auction 53 in September 2021, and continued rising at subsequent quarterly auctions.

There have been multiple studies that investigated the RGGI program, in terms of comparable CO_2 emissions markets and operations, periodical reports on bids, supply and clearing prices, as well as usage of the proceeds in energy projects. However, there was no study from the perspective of systems thinking that attempts to explain why the RGGI price has been on the rise, or system components to analyze the RGGI program. This paper aims to fill the gap by applying system dynamics methodology to investigate what caused the RGGI prices to keep rising and explore potential solutions how to maintain stability in the RGGI price. This paper is organized as follows: Introduction, Literature review, Analysis Results and Discussion, and finally, Conclusion and Future Research.

2. Literature Review

2.1 CO_2 Emissions Markets in North America

Besides the RGGI program in the Northeastern United States, as of March 2026, there are three existing CO_2 emissions markets in North America: California, Quebec in Canada, and Mexico.

California's cap-and-trade program, launched in 2013, constitutes a mature subnational emissions trading system based on the polluter-pays principle and the treatment of the atmosphere as a common property resource. The program mandates economy-wide emissions reductions through a declining cap and allows regulated entities to comply via allowance-surrender, banking, limited offsets, and secondary-market transactions [8]. Following its expansion to transportation fuels and natural gas in 2015, subsequent legislation extended the program through 2030, introduced price containment mechanisms, and stabilized investment expectations by reducing regulatory uncertainty [9].

The system covers approximately 80% of California's greenhouse gas emissions and is linked with Canada Quebec's emissions trading system under the Western Climate Initiative (WCI), forming the largest fully integrated subnational carbon market to date [8]. Recent auctions exhibit stable prices, full subscription, and modest contango between current- and advance-vintage allowances, indicating expectations of future cap tightening rather than speculative volatility [10, 11]. Empirical evidence suggests that emissions reductions under California's cap-and-trade program have been highly uneven across sectors. The electricity sector achieved the most substantial mitigation outcomes, with emissions estimated to be 48% below counterfactual levels by 2019, driven by the interaction of carbon pricing with renewable portfolio standards and fuel switching [12].

In Canada, Quebec's cap-and-trade system, formally known as SPEDE, was launched in 2012 and constitutes the core market-based instrument of the province's climate policy. Also anchored in the polluter-pays principle and intergenerational equity, the system establishes an economy-wide declining emissions cap and permits compliance through allowance surrender, banking, limited offset use, and secondary-market trading [13, 14]. The SPEDE covers approximately 80% of Quebec's greenhouse gas emissions, including large industrial emitters and fuel distributors, thereby extending carbon pricing to transportation and building-related emissions through upstream fuel coverage [15]. Since 2014, Quebec's system has been fully linked with California. Quebec has achieved roughly a 20% reduction in reported greenhouse gas emissions relative to 1990 levels, meeting its initial 2020 target. However, disaggregated analyses reveal that internal, within-province emissions reductions have been more modest, approximately 8–9% between 1990 and 2023, once allowance purchases from California are excluded [16].

Mexico's market framework is anchored in the General Law enacted in 2012, which established one of the earliest comprehensive climate governance systems among emerging economies. Following the 2018 reform aligning domestic law with the Paris Agreement, Mexico formally mandated the implementation of a national emissions trading system (ETS) as a core mitigation instrument to achieve its Nationally Determined Contribution (NDC) targets [17, 18]. The system operates under a cap-and-trade framework, supported by the National Emissions Registry (RENE), which provides the measurement, reporting, and verification (MRV) backbone for carbon pricing across sectors. Reductions to date have been driven primarily by complementary policies rather than the ETS itself, including fuel switching in the power sector and efficiency improvements in large industrial facilities. Scholars caution that the extensive free allocation of allowances and the potential expansion of offset use, currently capped at 10% but under consideration for increase, may dilute near-term abatement incentives within covered sectors [17].

2.2 Carbon Pricing and Electricity Market Effects

Empirical evidence indicates that the price effects of the RGGI have changed over time and were significantly influenced by policy strength and market design. Using firm-level panel data from 2004 to 2013, a study finds that RGGI-regulated electricity producers reduced net electricity generation by approximately 31,313 MWh per month relative to non-regulated firms [19]. Given that the average monthly output in the sample was 126,910 MWhs, this represents nearly a 25% reduction in generation. These results suggest that allowance costs initially functioned similarly to an implicit carbon tax, suppressing electricity supply in the short run. Market design mechanisms further influenced price stability. Friesen et al. (2022) analyzed the design of the RGGI's Cost Containment Reserve (CCR) and Emissions Containment Reserve (ECR) using experimental economics. Based on 2021 data, the ECR was set at approximately 10% of the annual total emissions cap and triggers when the auction price falls below $6 per ton. Conversely, the CCR provides additional supply when prices exceed $13. The results showed that changes in the trigger price significantly altered the average price. For example, while the control group average was $4.45, lowering the lower trigger reduced it to $3.76. In contrast, changes in the reserve size had a relatively small effect [20].

Zhou et al. (2024) incorporates intertemporal production constraints into a dynamic model using hourly PJM generator-level data (2009–2013). The study estimates that RGGI reduced fossil fuel emissions in Delaware and Maryland by at least 4.73%. A 1% increase in carbon prices is associated with a 1.85% reduction in emissions, and simulations indicate that a carbon price of $15 per ton could reduce emissions by approximately 23.5% [21]. Song and Hochman (2024) examined three major RGGI policy which was announced in 2005, implemented in 2009, and tightened in 2014. The study finds that neither the 2005 announcement nor the 2009 implementation led to statistically significant increases in wholesale electricity prices. However, following the substantial tightening of the emissions cap in 2014, wholesale prices increased by approximately $6.8–$55.7 per MWh, while retail prices rose by 0.3–0.8 cents per KWh. At the same time, RGGI states shifted their energy structure from coal and oil generation toward cleaner energy sources. These findings suggest that environmental regulation does not necessarily raise electricity prices in the short term, but once allowance scarcity becomes binding, carbon costs are reflected in market prices [22].

2.3 CO_2 Emissions Reduction and Fuel Switching

Several research suggest that RGGI has generated measurable CO_2 reductions, although net effects are moderated by leakage. The RGGI leakage represents the unintended increase in greenhouse gas emissions from non-RGGI states when power generation shifts from high-cost, capped power plants inside the RGGI region to uncapped power plants outside the region. Using plant-level data from 2000–2013, Metcalfe (2015) estimates that RGGI reduced annual CO_2 emissions in New York and New Jersey by approximately 4.9 million short tons. Associated declines in SO_2, NO_x, PM2.5, and PM10 generated co-benefits valued at roughly $130 million annually in New Jersey [23]. Expanding to a broader regional scope, Yan finds that RGGI states reduced coal consumption by 73% and natural gas consumption by 30%, resulting in approximately 4.8 million tons of annual CO_2 reductions. However, adjacent non-RGGI states experienced a 237% increase in natural gas consumption, generating roughly 3.5 million tons of additional CO_2 emissions, leaving net reductions at only 1.3 million tons per year. Model-based projections further reinforce both mitigation potential and leakage risks [24].

Lee and Yu (2025) identify internal leakage arising from RGGI's 25 MW threshold. While large plants shifted approximately 0.58 trillion BTU from coal to gas per $1 increase in carbon price, smaller unregulated plants increased coal use, partially offsetting reductions [25, 26]. Fu et al. (2025) show in a two-bus simulation that imposing a 2,000-ton cap on the regulated region reduces its emissions from 4,500 to 2,000 tons but increases emissions in the unregulated region from 500 to 3,000 tons, leaving total emissions unchanged [27].

2.4 Labor Market Impacts, Health, and Distributional Outcomes

Despite concerns that carbon pricing would suppress employment and economic activity, empirical evidence suggests that RGGI did not generate labor market disruptions. Gittings and Roach (2024) find no statistically significant effects of RGGI adoption (2009) or cap tightening (2014) on overall employment, wages, or industrial electricity prices. However, within the utility sector, job destruction rates increased by approximately 161% and worker reallocation rates rose by 61%, indicating substantial labor restructuring without net employment decline [28].

Beyond electricity generation and fuel markets, empirical evidence indicates that RGGI has generated significant impacts in labor and regional economic markets through the recycling of allowance auction revenues. According to the Analysis Group's economic impact assessment for the fourth compliance period (2018–2020), RGGI generated approximately $669 million in net economic value in 2021 dollars across participating states, equivalent to roughly $15 per capita in net positive value added. Over the same period, RGGI-supported investments were associated with the creation of approximately 7,874 cumulative job-years, primarily in labor-intensive sectors such as energy efficiency retrofits, renewable energy installation, program administration, and workforce training. These employment gains reflect a reallocation of economic activity from capital-intensive fossil fuel generation toward service- and construction-oriented clean energy activities, suggesting that RGGI's market impacts extend into labor demand and income generation rather than remaining confined to the power sector [29].

Beyond emissions reductions and economic outcomes, a growing body of research examines the environmental and social distributional consequences of RGGI. Yang et al (2021) simulates Pennsylvania's entry into RGGI and estimates that by 2030, in-state CO_2 emissions would decline by 51.8%, alongside reductions of 85.5% (SO_2) and 83.6% (PM2.5), generating cumulative health benefits of $17.7–40.8 billion. However, emissions and health burdens in non-RGGI states are projected to increase by 14–16%, indicating interstate burden shifting [30].

Declet-Barreto and Rosenberg analyzed power plant locations and demographic exposures from 1995 to 2015, and found that Environmental Justice (EJ) communities, defined by an average 65.8% non-white population and 19.0% poverty rate, were disproportionately located near power plants. Although emissions declined and fuel switching toward natural gas progressed more rapidly in EJ areas, aggregate reductions did not automatically eliminate preexisting inequities [31].

Taken together, these studies indicate that RGGI produces measurable public health co-benefits, yet distributional outcomes depend heavily on plant location, demographic composition, and interstate electricity trade patterns. While aggregate emissions and pollution levels decline, preexisting environmental justice disparities do not automatically disappear, and in some cases may persist or shift geographically. These findings suggest that carbon pricing alone is insufficient to ensure equitable environmental outcomes, underscoring the importance of complementary policies that explicitly address community-level exposure and cross-state spillovers.

3. Analysis Results and Discussion: Behavior over Time

The behavior over time chart of the RGGI auction clearing prices, as shown Figure 1, clearly shows that the structure and behavior of the RGGI clearing price follows that of exponential growth in the past 70 auctions, not that of goal setting oscillation. Nevertheless, it is certain that the fundamental behavior mode could produce one of the following: an S-shaped growth, overshoot and collapse, stasis-equilibrium, or randomness, according to the definitions of structure and behavior of a dynamic system [32]. However, when and how the price behavior will stay stable are the questions to be answered.

RGGI, Inc. publishes quarterly auction results to the public, including Clearing Price, RGGI Quantity Sold, Total Proceeds, Potential Bidders, Ratio of Bidders, Ratio of Bids to Initial Supply, and Percentage Won by Compliance Entities. Table 1 presents a detailed summary of descriptive statistics of the RGGI auction results. In the past seventy quarterly auctions, the RGGI Price was in the large range of $1.86 to $26.73, while Quantity Sold was 7.5 million short tons to 42 million short tons. As to bidding participants, the number of Potential Bidders was 29 to 90, with Ratio of Bids to Initial Supply in the range of 0.18 to 4.10. Finally, Percentage Won by Compliance Entities was 36% low to 100% high.

Table 1. Descriptive Statistics: RGGI Auction Results in the Past 70 Auctions

	N	Minimum	Maximum	Mean	Std. Deviation
Clearing Price ($/short ton)	70	1.86	26.73	7.27	6.31
Quantity Sold (ton)	70	7,487,000	41,995,813	21,308,926	8,283,307
Total Proceeds ($)	70	14,150,430	464,893,520	14,4647,695	119,537,272
Potential Bidders	70	29	90	58.36	13.55
Ratio of Bids to Initial Supply	70	.18	4.10	2.32	.84
Won by Compliance Entities	70	.36	1.00	.72	.16

Table 2. Boxplot Charts of RGGI Auction Results

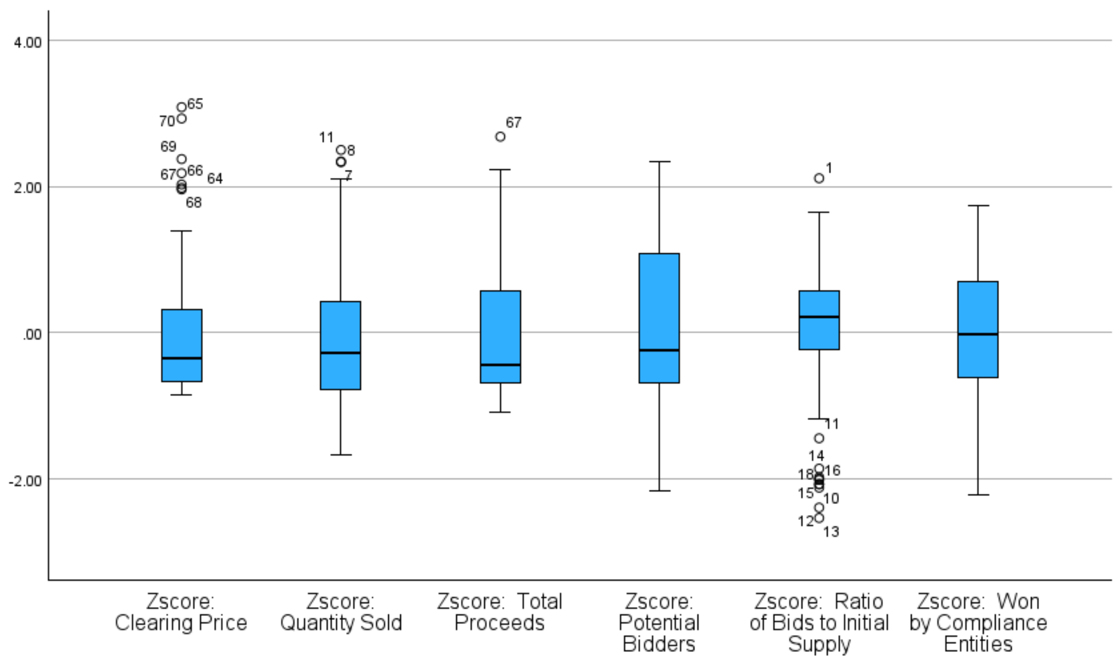

Table 2 displays the Boxplot Charts of the quarterly variables in the RGGI auction results. When compared with standardized z-scores of the result variables, the two variables of Clearing Price and Ratio of Bids to Initial Supply, show the most outliers in particular, which started appearing in the 2023 auction for the first variable and in 2011 and 2012 auctions for the second, respectively. The auction result variables showing the widest variability, in terms of interquartile range (IQR), include Quantity Sold, Potential Bidders, and Percentage Won by Compliance

Entities.

Correlation coefficients are also calculated to measure the magnitude of relationships among the variables. All the coefficients related to the RGGI Price look intuitively reasonable, considering the laws of supply and demand. The correlation details are summarized in Table 3. The variables that positively correlated to the RGGI Price include Total Proceeds and the number of Potential Bidders, while those negatively correlated are Quantity sold and Percentage Won by Compliance Entities.

Table 3. Correlation Matrix among the Variables: RGGI Results

	Clearing Price ($/ton)	Quantity Sold (ton)	Total Proceeds ($)	Potential Bidders	Ratio of Bids to Initial Supply	Won by Compliance Entities
Clearing Price ($/ton)	1.00					
Quantity Sold (ton)	(0.21)	1.00				
Total Proceeds ($)	0.93	0.05	1.00			
Potential Bidders	0.60	0.12	0.70	1.00		
Ratio of Bids to Initial Supply	0.31	(0.22)	0.28	0.48	1.00	
Won by Compliance Entities	(0.26)	0.11	(0.26)	(0.17)	(0.49)	1.00

4. Analysis Results and Discussion: Causal Loop Diagrams

4.1 RGGI Allowances Supply

Causal Loop Diagram Figure 2 portrays how the RGGI auction operates to reach the RGGI clearing prices, from the perspective of RGGI allowances supply. RGGI Price is negatively affected by Auction Supply that represents short-term allowance availability in the primary RGGI market. Given RGGI's reliance on centralized auctions for allowance distribution, changes in auction volume directly affect liquidity. Reductions in auction supply increase scarcity and exert upward pressure on prices, particularly when compliance demand remains stable.

The RGGI Price plays a role of a trigger to Cost Containment Reserve (CCR) and Emissions Containment Reserve (ECR). The CCR and ECR function as automatic stabilizers designed to moderate price volatility in the RGGI market [4]. The CCR releases additional allowances when auction prices exceed a predefined trigger, introducing a price-responsive expansion of supply. By contrast, the ECR withholds allowances from auction when prices fall below a specified threshold, thereby tightening supply during periods of weak demand [33].

Together, these mechanisms establish a soft price ceiling and floor that shape market expectations regarding the feasible trading range. When the CCR trigger is reached, the temporary increase in supply can alleviate upward price pressure. However, once the annual CCR volume is fully exhausted, the market reverts to the fixed cap, heightening exposure to scarcity. In 2025, the CCR trigger price was set at $17.03 per short ton [34]. During Auction 67 in March 2025, clearing prices exceeded this threshold, resulting in the release and sale of the full 2025 CCR allocation of 8,134,778 allowances [1]. Because the CCR is replenished only at the start of each calendar year, no additional reserve supply remained available for the remainder of 2025 [35]. The exhaustion of the CCR effectively removed the soft price ceiling, contributing to the elevated clearing price of \$26.73 observed in Auction 70 [35].

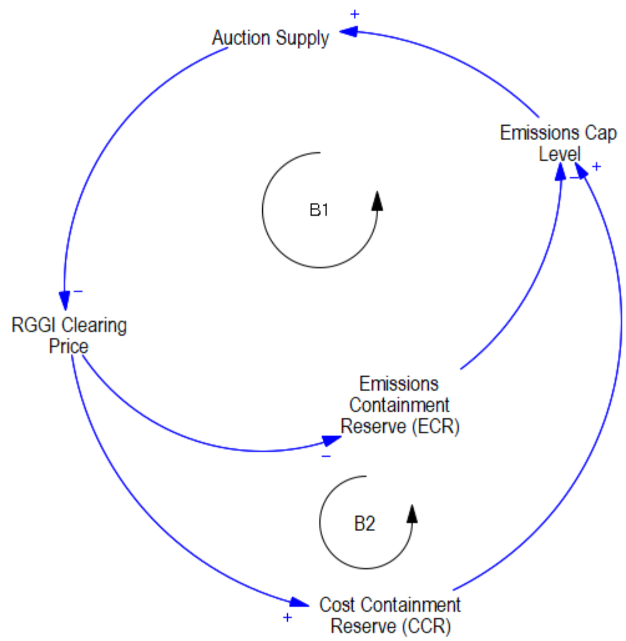

Figure 2. Causal Loop Diagram: RGGI Allowances Supply

The regional CO_2 Emissions Cap establishes the absolute upper bound on the number of short tons of CO_2 that regulated sources within participating states are permitted to emit during a given compliance period [4]. As the core scarcity-generating instrument of the Regional Greenhouse Gas Initiative, the cap plays a central role in determining allowance prices. Both ECR and CCR affect the CO_2 Emissions Cap, in a negative and a positive manner, respectively. Notably, the ECR helps, by creating a balancing feedback loop B1 in Figure 2, to decrease the Emission Cap and help raise the RGGI Price, and in contrast, the CCR in B2 contributes to increasing the Cap and then helping lower the price.

By the program design, the Emissions Cap declines over time, signaling a progressively tightening supply of allowances and incentivizing regulated entities to invest in lower-carbon technologies. The price impact of cap tightening operates primarily through the marginal cost of abatement. As allowable emissions decrease, firms are compelled to adopt increasingly costly abatement measures, a dynamic that is reflected in higher auction clearing prices. In 2021, the regional cap was set at 119,767,784 allowances, declining to 81,347,784 allowances by 2025 [4]. Beginning in 2027, the cap will fall to 69,806,919 tons and subsequently decline by approximately 10.5% of the 2025 budget annually through 2033 [33]. This trajectory implies a reduction to roughly 9 million tons by 2037, constituting a strong bullish signal to market participants anticipating severe future supply constraints [33].

4.2 RGGI Allowances Demand

Causal Loop Diagram Figure 3 represents the operations on demand side of the RGGI auction, with three feedback loops: R1, B3 and B4. The reinforcing feedback loop R1 on the left of Figure 3 depicts how interactions are taking place among Actual Emissions-to-Cap Ratio, Policy Credibility and Long-Term Commitment, and Bidders' Banked Allowances, affecting the stock variable Total RGGI Demand.

Total RGGI Demand increases Actual Emissions-to-Cap Ratio that measures market tightness by comparing verified emissions from covered sources with the annual allowance budget [4]. When actual emissions exceed the effective emissions cap, after accounting for banked allowances, scarcity intensifies, compelling firms to draw down banks or undertake additional abatement, both of which influence demand and prices. Conversely, emissions well below the cap facilitate surplus accumulation, dampening immediate price pressure. This high ratio mitigates Policy Credibility and Long-Term Commitment. Policy Credibility reflects market participants' perceptions regarding the durability and stringency of the RGGI program. High policy credibility is important in that it encourages allowance banking in anticipation of future scarcity, raising current prices but reducing the RGGI demand, whereas political or legal uncertainty weakens banking incentives and increases price volatility [36]. The withdrawal of Virginia in 2023 via executive action, later ruled unlawful by a state court in November 2024, introduced significant uncertainty into regional supply-demand expectations [37]. Similarly, ongoing litigation concerning Pennsylvania's participation has sidelined a substantial portion of potential demand [38].

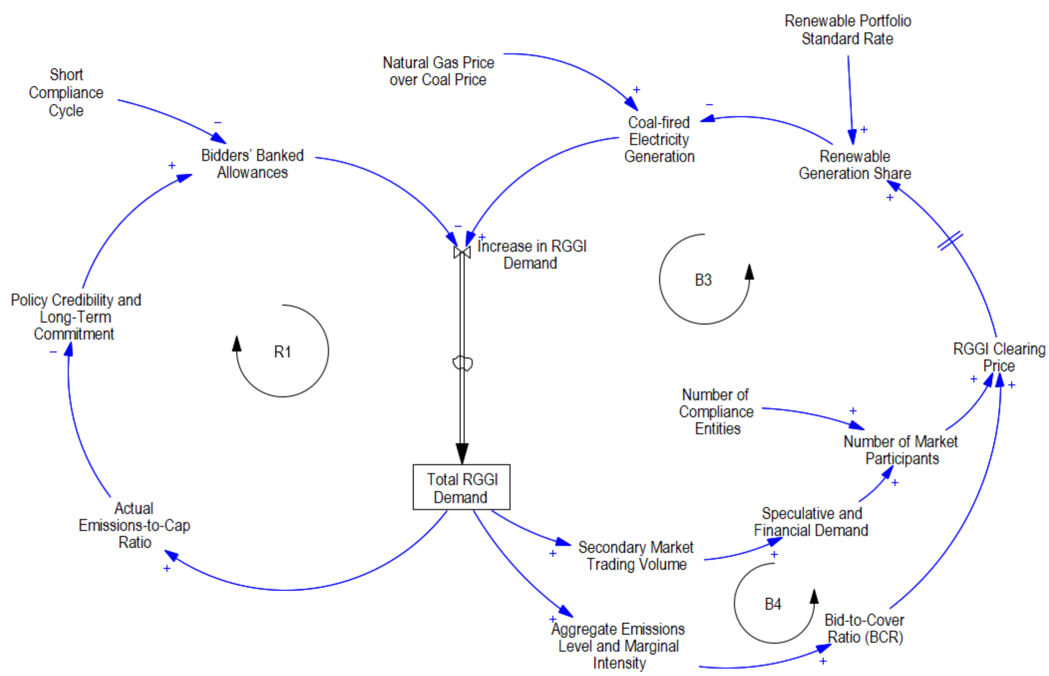

Figure 3. Causal Loop Diagram: RGGI Allowances Demand

When the Policy Credibility and Long-Term Commitment help the bidders to trust the RGGI program and bank the emissions allowances. Banked allowances represent the cumulative surplus of allowances retained by market participants from previous compliance years that have not yet been surrendered [33]. Because RGGI allowances do not expire and may be carried forward indefinitely, a large allowance bank can dampen prices by serving as an alternative source of supply alongside quarterly auctions. In this sense, the allowance bank functions as a buffer to reduce the RGGI demand against short-term supply shocks. Meanwhile, short Compliance Cycle, which currently is three (3) years, discourages the bidders from accumulating more allowances.

RGGI operates through three-year control periods, during which regulated sources must surrender one allowance per ton of verified CO_2 emissions [4]. Interim compliance requirements mandate that entities hold allowances covering 50% of their annual emissions at the end of each year [39]. This structure shapes the temporal distribution of demand, as firms may defer allowance purchases early in a control period and accelerate acquisition as interim or final deadlines approach. Such clustering of demand can amplify short-term price pressure, particularly when auction supply is constrained. As compliance deadlines near, entities facing shortfalls must bid more aggressively in primary auctions or rely on secondary markets, intensifying upward price movements. Moreover, when allowances are increasingly held by compliance-oriented entities, effective tradable supply declines, reducing liquidity and increasing price sensitivity to incremental demand shocks [40].

Balancing feedback loop B3 on top right of Figure 3 focuses on the contribution of Renewable Portfolio Standards and their effects on Renewable Generation Share in the power sector, compelled with time delay by higher RGGI Price. Growth in renewable and nuclear generation structurally reduces the proportion of Coal-fired Electricity Generation, and ultimately, RGGI Demand by displacing fossil fuel output. However, variability in clean resource availability can introduce short-term shocks. In 2024, New England experienced a 32% decline in hydropower imports from Canada due to drought conditions, leading to an 8% increase in natural gas generation and a 28% year-over-year increase in coal generation [41]. This shift temporarily increased allowance demand, illustrating how reliability constraints can amplify price volatility even amid expanding renewable capacity.

The Coal-fired Generation is also negatively affected when the natural gas price is lower than the coal price per MMBtu basis. Natural gas dominates electricity generation within the RGGI region, making relative fuel prices a key determinant of short-run emissions outcomes. When natural gas prices are low relative to coal, gas-fired generation displaces coal, reducing emissions and allowance demand. Conversely, higher gas prices can render coal generation economically viable despite its higher emissions intensity, increasing emissions and allowance demand [42]. Coal prices establish the baseline economics of generation costs. Because coal-fired units emit roughly twice as much CO_2 per MWh as gas-fired plants, they require approximately double the number of allowances. Consequently, periods in which coal becomes relatively cheaper, particularly during gas price spikes, can shift dispatch toward coal, raising allowance demand and carbon prices.

Increased Total RGGI Demand also encourages RGGI Bidders to participate in RGGI Secondary Market, attracting more of Speculative and Financial Demand, who look for profit opportunities at the volatile RRGI marketplace, resulting in higher clearing prices in RGGI auctions. Speculative demand in the RGGI market is driven by expectations of long-term price appreciation resulting from a declining cap [36]. Secondary market activity for RGGI futures includes physical allowance trades and derivatives traded on platforms such as ICE (Intercontinental Exchange) and Nodal Exchange [43]. Trading volumes in 2025 were robust but volatile, reaching 124 million allowances in Q1 before declining to ninety million in Q3 as participants absorbed Program Review outcomes [43]. Total open interest stood at approximately 115 million allowances at the end of Q3 2025 [40]. Option-implied volatility doubled in early 2024 and remained elevated, reflecting heightened policy uncertainty [43]. This volatility attracts speculative capital, which can temporarily drive prices away from compliance-based fundamentals [40].

Speculative and Financial Demand in the feedback loop B3 also affects the number of market participants, along with Number of Compliance Entities, finally driving up RGGI Clearing Price. RGGI participation comprises three groups: Compliance Entities, Compliance-Oriented Entities, and pure financial investors [35]. Auction seventy reflected a competitive participant mix, with 49 bidders and broadly distributed bids [35]. Compliance Entities purchased 54% of allowances, below the historical average of 72%, while the remainder was acquired by investors [35]. This shift indicates that prices are increasingly influenced by financial considerations—such as portfolio diversification and inflation hedging—rather than purely compliance-driven demand [40].

In Figure 3 on bottom right is the balancing feedback loop B4, which presents how the current level of Total CO_2 Emissions drives up the RGGI Clearing Price by increasing Bid-to-Cover Ratio (BCR) in the auctions. Aggregate Emissions determine total compliance obligations and directly influence allowance demand. Beyond total emissions, marginal emissions intensity governs price transmission. In competitive electricity markets, the marginal unit sets wholesale prices, embedding carbon costs into electricity prices when the marginal generator is emissions intensive. In 2024, ISO New England reported that natural gas was the marginal fuel for approximately 81% of load, with a time-weighted marginal emissions rate of 899 lbs/MWh [41]. This implies that each additional MWh of demand generates roughly 0.45 tons of CO_2. At allowance prices of $26 in 2025, the implied carbon cost added approximately $11.70 per MWh to marginal generation costs [35]. The Bid-to-Cover Ratio measures auction demand relative to supply. High ratios indicate strong demand and typically correspond to higher clearing prices [1]. RGGI auctions have remained consistently oversubscribed. Auction 70 recorded a BCR of 2.40, [35] while Auction 67 maintained a BCR of 3.70 despite the release of over 8 million CCR allowances [1]. Persistent oversubscription suggests rationed demand and implies that equilibrium prices may exceed observed clearing prices [35], which will result in attracting more renewable generation and reducing coal-fired generation and RGGI demand.

5. Conclusion and Future Research

This study investigated how the rising RGGI clearing prices may be explained by a systems thinking approach. In the Behavior over Time chart in RGGI Price, we find that the RGGI Price started spiking in double digits in 2021 and kept rising, and in Box Plot chart of the variables in RGGI Auction Results, the RGGI Price showed many outliers outside the max and min whiskers, together with Ratio of Bids to Initial Supply. The variables showing the largest variability include Quantity Sold, Potential Bidders, and Won by Compliance Entities. The correlation coefficients among the variables reveal that the RGGI Price is positively correlated to components that lead to increased demand for emissions allowances, and negatively correlated to components that contribute to increased supply, in line with the laws of supply and demand.

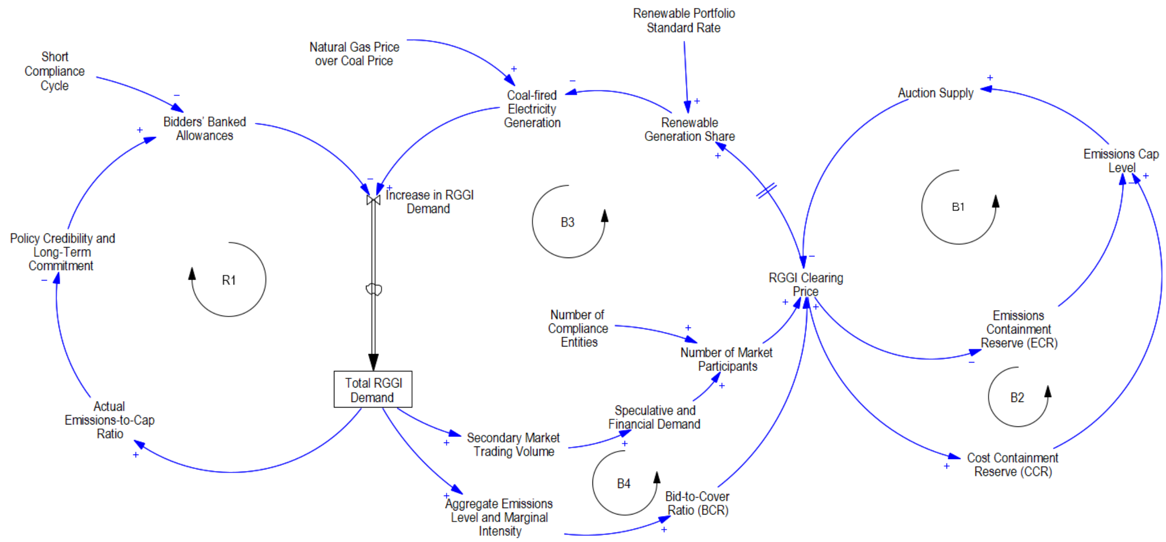

Figure 4. Integrated Causal Loop Diagram: Supply and Demand for RGGI Allowances

Causal Loop Diagram visually explains how and why the RGGI Price has been on the rise in the past seventy quarterly auctions. Figure 4 represents the integrated causal loop diagrams from the perspectives of both supply and demand sides. When looking at the supply side of the RGGI allowances, balancing feedback loops B1 and B2 are observed, where Cost Containment Reserve (CCR), price triggered mechanism, directly increase Auction Supply, while Emissions Containment Reserve (ECR) operates to decrease the Supply in the opposite direction of CCR. These two balancing feedback loops on auction supply side suggest that increased quantity of Emissions Cap Level and CCR will help reduce the RGGI Price, with ECR working to help increase the Price on the other hand.

On demand side, the reinforcing feedback loop R1 indicates that Total RGGI Demand may be reduced by Policy Credibility and Long-Term Commitment, a longer Compliance Cycle, and Bidders' Banked Allowances. In this case, the interventions to lengthen the Compliance Cycle along with more credible policy will serve as practical solutions to reduce RGGI demand thus stabilizing the RGGI Price.

There are also two feedback loops, B3 and B4, on demand side in Figure 4. The balancing feedback loop B3 describes increased Renewable Generation Share, driven by higher RGGI Clearing Price and Renewable Portfolio Standards, will help reduce Total RGGI Demand, while Speculative and Financial Demand pushes up the RGGI Price. The balancing feedback loop B3 suggests two possible interventions: increased mandatory RPS requirements and a new policy to exclude speculative and financial investors in RGGI auctions. The balancing feedback B4 on RGGI demand side indicates that Aggregate Emissions Level means more bidding quantity than the available emissions cap for an auction, resulting in higher RGGI Price. This loop B4 also suggests that reducing Total RGGI Demand is a key to reaching a low RGGI Price.

In conclusion, the policy interventions to lower the RGGI Price could take place on two ends: supply and demand for RGGI allowances. On the supply side, the interventions include increasing the emissions cap and CCR on the supply side, while on the demand side they include encouraging RGGI Bidders to bank more allowances for longer compliance cycle and making more credible and long-term oriented policy. Also, reducing Total RGGI Demand by providing more Renewable Generation with stricter RPS will definitely help lower the RGGI Demand and then RGGI Clearing Price.

This study investigated why the RGGI Price experienced price spikes over the seventy quarterly auctions, in terms of limited situations: supply and demand for RGGI allowances, as well as explored policy interventions to lower the RGGI Price with levering the components of RGGI supply and demand. The authors find it meaningful to see future research investigate how macroeconomic factors in the RGGI participating states affect the RGGI Clearing Price and how the states are also affected by higher RGGI Prices in macroeconomy. Another interesting topic would be what impact substitute markets would have on the Regional Greenhouse Gas Initiative.

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