10 YEARS OF CAP AND TRADE

A COMPREHENSIVE REVIEW OF THE REGIONAL GREENHOUSE GAS INITIATIVE

by
Adam L. Rich

A capstone submitted to Johns Hopkins University in conformity with the requirements for the degree of Master of Science in Energy Policy and Climate

Baltimore, Maryland
April 2018

Executive Summary

The Regional Greenhouse Gas Initiative was the first greenhouse gas-focused cap-and-trade program in the United States. Encompassing nine states in the northeast region of the country, the program covers carbon dioxide emissions from large-scale fossil-based electric power generators.

Over the course of the last decade, the Initiative has helped make substantial progress in reducing emissions and changing the generation portfolio in the region, as seen in data from governments, independent system operators, and RGGI itself. It has helped to encourage the reduction of coal and petroleum as sources of electric generation, while encouraging the adoption of renewable generation, and collectively reducing emissions among RGGI states by over 22%, far exceeding the rest of the nation.

While RGGI has been a major factor in emissions reduction and the shifts in the region's generation portfolio, it is not likely the only reason. Other factors, including the cost of energy, Renewable Portfolio Standards, and the potential for emissions leakage, all have had an impact on sources of electric generation and emissions reduction.

Ultimately, the Initiative has been successful in its goal of reducing greenhouse gas emissions and improving the region's generation portfolio. While not without its drawbacks, including the overallocation of carbon allowances, and the potential for leakage, the program does have the potential for long-term improvement by expanding sector coverage and eliminating sources of leakage.

Table of Contents

Overview

The Regional Greenhouse Gas Initiative (also referred to here as "RGGI," "the Program," or "the Initiative") was the first collaborative greenhouse gas cap-and-trade program implemented in the United States. Currently encompassing nine states in the northeast region of the country, the program seeks to reduce carbon dioxide emissions from the electric generation sector within the participating states (Bifera 2013, 1). In order to analyze the program, it is first important to understand its origins and structure.

In order to understand the Regional Greenhouse Gas Initiative, it is helpful to understand the basics of a cap-and-trade system. Cap-and-trade is an economic mechanism used to control the output of a given market. In the context of emissions control, it is also known as an emissions trading system. The name itself is fairly self-explanatory. A state, country or multiple entities agree to place a cap on their collective emissions, gradually decreasing the cap over subsequent years in order to hit emissions reduction targets. Under the cap, allowances for emissions (carbon or other) are allocated to participating or covered entities either through free distribution or auction. The participating entities can then trade those allowances amongst each other in order to acquire sufficient allowances to cover their emissions (Bifera 2013, 1; Ramseur 2017, 2).

The Regional Greenhouse Gas Initiative was created during the mid-2000s, beginning with discussions among nine states in 2003 on the potential for creating a regional emissions control program. By 2005, seven of those states had signed a Memorandum of Understanding to join the Initiative, while three others followed suit in 2007. When the Program took effect on January 1, 2009, it officially became the first greenhouse gas-centric cap-and-trade program within the United States (RGGI Inc. n.d., "Program Design Archive").

The Initiative itself only covers carbon dioxide emissions from fossil fuel-powered power plants in the electric power sector. Plants that are affected by RGGI are required to obtain sufficient carbon allowances, at auction and through trade, to cover their carbon dioxide emissions (RGGI, Inc. n.d., "Elements of RGGI").

In the second control period, from 2012-2014, the Program underwent some notable changes. First, prior to the start of the control period, the State of New Jersey withdrew from the program, following which the emissions caps were adjusted to reflect the change. Secondly, in an effort to keep prices from becoming excessive due to high demand, the organization introduced a new price control mechanism to the auction system called the Cost Containment Reserve (or CCR). The CCR was designed to release additional carbon allowances at a fixed price should the auction clearing price exceed a certain level, effectively creating a price ceiling. The trigger price for the CCR increased annually, starting at $4 in 2014, increasing by $2/year until 2017 (reaching $10), 2.5%/year from 2018-2020, and rising to $13 in 2021, with future annual increases of 7%. The CCR has thus far only been used twice (Bifera 2013, 3-4, 6; RGGI, Inc. n.d., "Allowance Prices and Volumes"; RGGI, Inc. n.d., "Elements of RGGI").

In 2013, the program underwent a review process that resulted in an updated model rule which significantly reduced the emissions cap. In 2012 and 2013, the cap was set at 165 million tons of carbon dioxide, slightly lower due to the lost participation of New Jersey. In 2014, after the new model rule took effect, the cap decreased significantly to 91 million tons of carbon dioxide emissions, with further annual reductions of 2.5% through 2020. This substantial change in the cap drove up auction prices from $1.93 per ton to a peak of $3.21 per ton during the second control period (C2ES n.d. "Regional Greenhouse Gas Initiative (RGGI)"; RGGI, Inc. n.d., "Elements of RGGI").

The Cost Containment Reserve showed some success in keeping auction prices from getting too high. However, a separate price floor mechanism did not keep the auction price from falling below $4 per ton. This ultimately occurred as it had in previous control periods, due in part to the overallocation and subsequent banking of allowances. RGGI allows participants to bank allowances indefinitely, so if the program allocated too many allowances, it can hinder actual emissions reduction in future years through the banking of allowances, decreasing demand for allowances in the auctions, and potentially driving the price down (Bifera 2013, 5; Ramseur 2017, 7, 9-10).

In the third model rule for RGGI, the program will enact an additional price mechanism called the Emissions Containment Reserve in 2021, which allows individual states the option to hold back up to 10% of their allowances from auction in the event that the price falls below a certain level (starting at $6/ton and increasing by 7% every year thereafter), giving states the ability to potentially reduce emissions beyond the cap (C2ES n.d., "Regional Greenhouse Gas Initiative (RGGI)"; Ho & Morris 2017). While this could help stabilize prices, it also enhances the program's ability to reduce emissions.

Now in its tenth year, RGGI has become one of the premier examples of carbon trading. Looking back on the first decade of RGGI, this paper will provide a comprehensive review of the program as it relates to its goal of emissions reduction, also examining changes to generation as well as implementation of renewable energy sources, ultimately highlighting three general

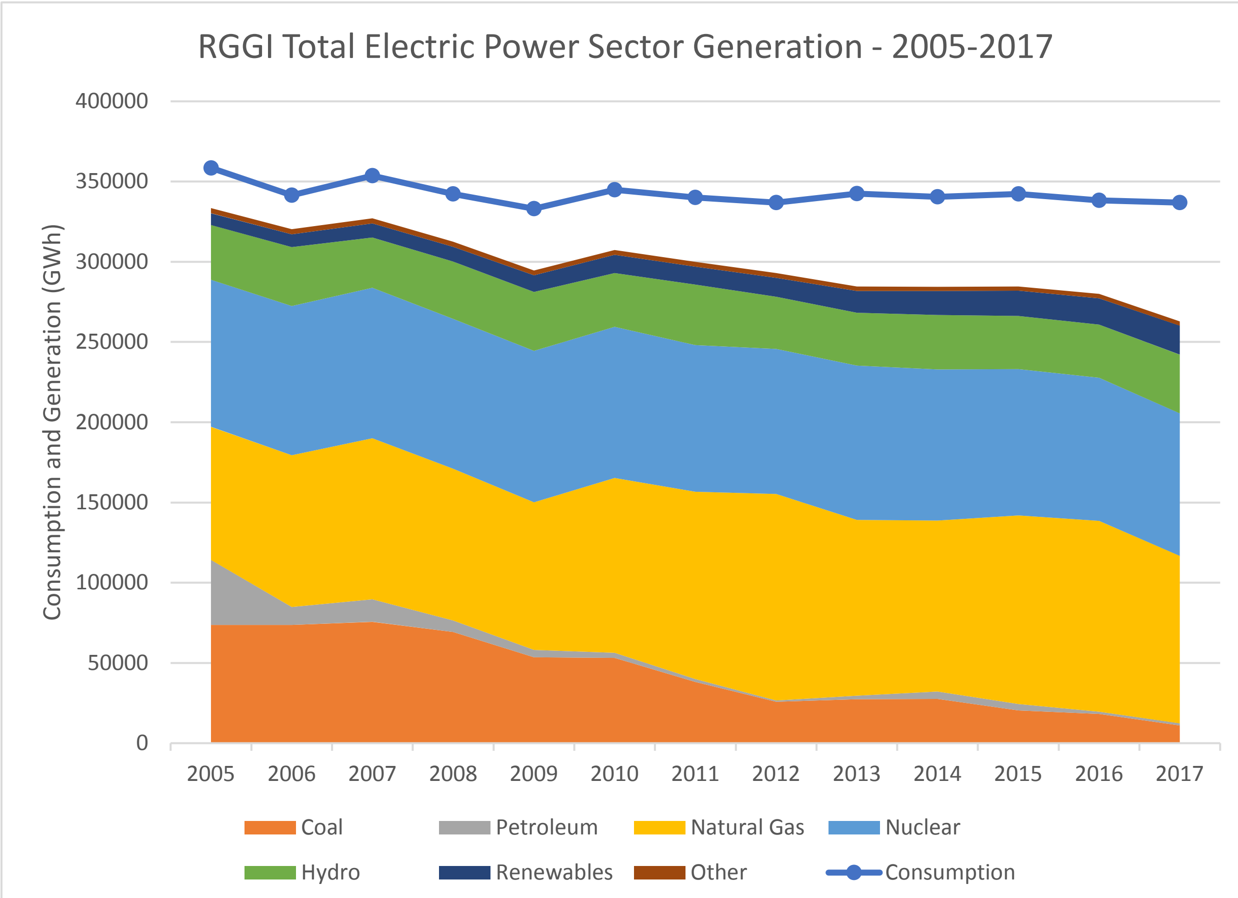

Figure 1 (See Appendix A and Appendix B for Data)
Data Source: U.S. EIA 2007-2018

aspects of RGGI: what works; what does not; and what could be improved. This paper will examine these elements of RGGI, looking at both emissions reduction and improvements in the regional energy portfolio, while examining its shortfalls and making recommendations for improvements to the program for the future.

Methods

In order to ascertain the success or failure of RGGI, multiple aspects must be examined. First, electric generation data for RGGI states will be examined to identify shifts in generation sources that may have resulted from the policy. Second, energy-related emissions data from RGGI states will be examined and compared to the rest of the nation to understand the effectiveness of the program in its primary objective. Thirdly, the program itself will be compared to other carbon pricing systems throughout the world to examine both scope and effectiveness. Finally, elements of the program will be broken out and highlighted to understand potential shortcomings.

Data and Analysis

The generation and emissions changes among RGGI states can be assessed using data from the U.S. Energy Information Administration (henceforth referred to as "EIA").[1] In order to put context to generation data, and its potential implications for the region, consumption data must be examined. Both generation and consumption data for the region are visually represented in Figure 1. In 2005, consumption, or what EIA categorizes as "sales of electricity to ultimate customer," within RGGI was 358,513 GWh, while "electric power sector" generation was 330,300 GWh (U.S. EIA 2007). This discrepancy between consumption and generation of over 28,000 GWh was likely filled by importing electricity from neighboring states and Canadian provinces. The gap between consumption and generation would continue to grow over the next 12 years. Based on data from the EIA, 2017 consumption within RGGI was 336,835 GWh, down by 6.1% from 2005 levels, however the consumption level was mostly flat over the previous eight years. Generation within RGGI states, on the other hand, decreased significantly to 262,872 GWh, a drop of 20.4%, leaving a gap of over 74,000 GWh between generation and consumption (U.S. EIA 2007; 2008; 2009; 2010; 2011; 2012; 2013; 2014; 2015; 2016; 2017;

[1] 2017 generation and consumption data provided by U.S. EIA is considered preliminary. All remaining generation and consumption data, as well as energy-related emissions data, is considered final.

2018)[2]. While overall generation in the region was decreasing, consumption remained relatively the same, meaning that RGGI states needed to import a greater amount of electricity in order to meet demand.

In terms of generation, from 2005 to 2017 the participating states collectively saw a substantial reduction in the use of coal and petroleum for electricity generation according to EIA data, with the states collectively reducing their coal-based generation by 85.1% and their petroleum-based generation by 96.8%. Petroleum-based generation dropped from 12.2% of total generation to just 0.5%, making it the least used energy source in the RGGI region. Coal decreased from 22.3% of total generation to 4.2%, most of which comes from Maryland. Natural gas, a cleaner-burning fossil fuel, saw significant increases over the same time period, with generation increasing by 26% over 2005 levels. As a result, natural gas is now the largest source of electric generation within RGGI, accounting for 39.7% of total generation, up from 25% (U.S. EIA 2007-2018).

EIA data shows that other sources of power also saw noticeable changes from 2005 to 2017. Nuclear power experienced a slight decrease in generation of 3.2%. However, due to the rebalancing of other sources, nuclear power's total share of generation increased by about 6.2%, despite no added nameplate capacity in the region. Additionally, other sources of generation (defined by EIA as "manufactured, supplemental gaseous fuel, propane, and waste gasses")[3] have experienced a noticeable decrease as a generation source since 2005. In the

---

[2] In an effort to save space and prevent an abnormally long citation, this citation will be henceforth referred to as "U.S. EIA 2007-2018"

[3] For purposes of this analysis, the EIA category "Other Energy Sources" has been combined with the category "Other Gases."

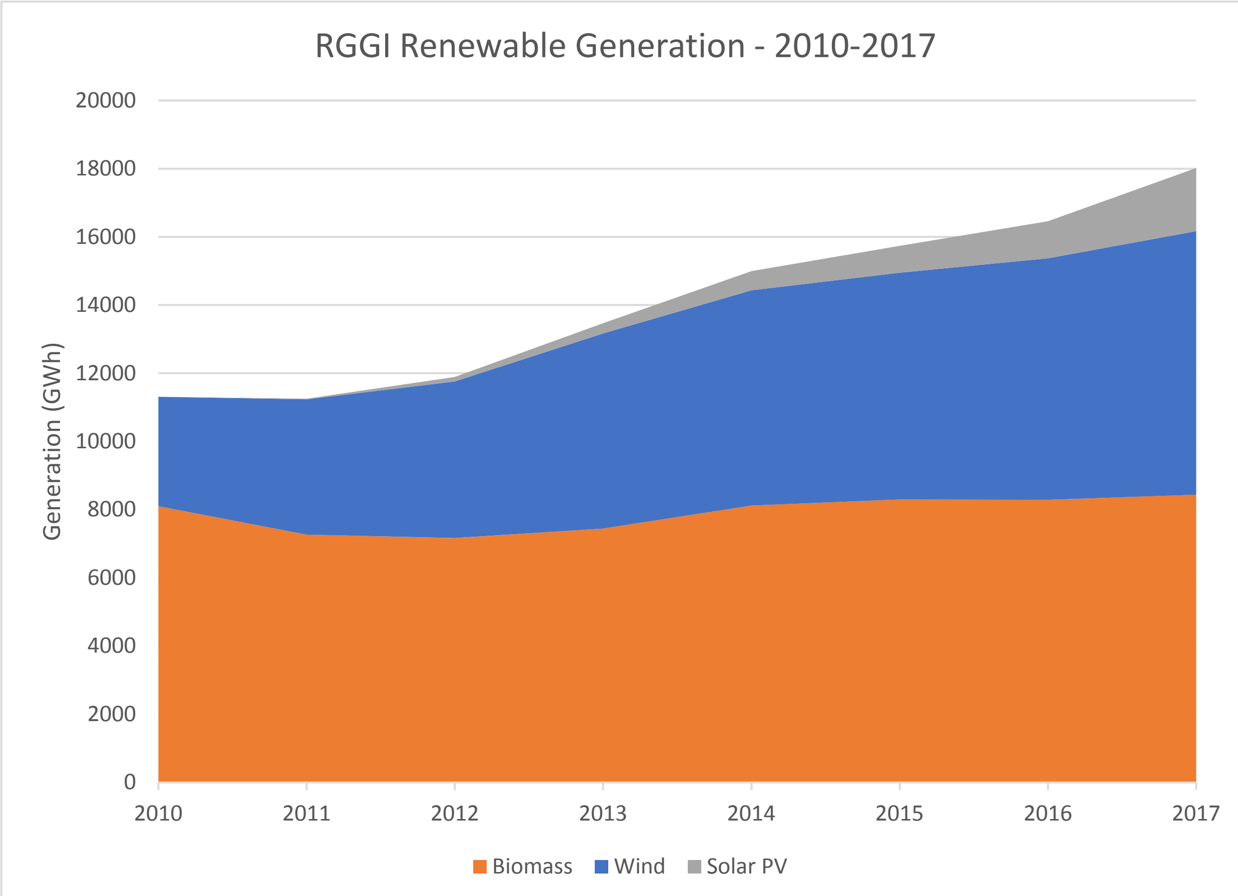

Figure 2 (See Appendix C for Data)
Data Source: U.S. EIA 2007-2018

intervening years, the states in RGGI have removed 20.2% of generation capacity from other sources to their portfolios. While it still only accounts for 1% of total generation, it has surpassed petroleum in market share within RGGI (U.S. EIA 2007-2018).

Renewables and hydroelectric generation also saw increases since 2005. Hydroelectric generation saw minimal change in output, although by 2017 it accounted for 13.9% of total generation in RGGI, up from 10.3% in 2005 according to EIA data. The majority of hydropower in RGGI is generated in the state of New York, which generates 78% of all hydropower in the collective. Renewable generation experienced the largest increase among all sources used in RGGI. From 2005 to 2017, renewable generation (defined by EIA as all renewables except hydro) increased by 149.3%, increasing its share of total generation from 2.2% to 6.9%, with much of the added generation coming from New England and New York. While hydropower and renewables account for a comparatively modest portion of generation within RGGI, the collective increase from 12.5% to 20.8% is a substantial improvement, one likely to continue in the coming years (U.S. EIA 2007-2018).

Looking more closely at renewable generation reveals deeper insights into the changing generation portfolio within RGGI. Renewable energy comes from three sources within RGGI: biomass; wind power; and utility-scale solar photovoltaic (PV), as can be seen in Figure 2. Since 2010, when the EIA began breaking out data for individual renewable sources, biomass has remained relatively flat, up slightly (4.2%) from 2010, although there was a noticeable dip in biomass-based generation from 2011-2013 (U.S. EIA 2007-2018). Biomass, however, is potentially controversial. While it is technically renewable, in the sense that the plants that source it can regrow, biomass is burned in order to generate electricity, and that process releases carbon dioxide into the atmosphere (NREL n.d., "Biomass Energy Basics").

The major sources of the increase in renewable generation come from wind and solar. Wind, compared to 2010, increased by 140.5% by 2017, adding more than 3500 GWh of generation over 2010 levels. Most of the increase in wind came from New York and the New England states, although Maryland also saw a substantial increase in wind generation. On a percentage basis, however, the increase in solar was unmatched. In 2010, there was 1 GWh of solar PV generation in the region. By 2017, this had increased to 1851 GWh. Over 1200 GWh of solar was generated in New England, with over 1000 GWh generated in Massachusetts alone (U.S. EIA 2007-2018).

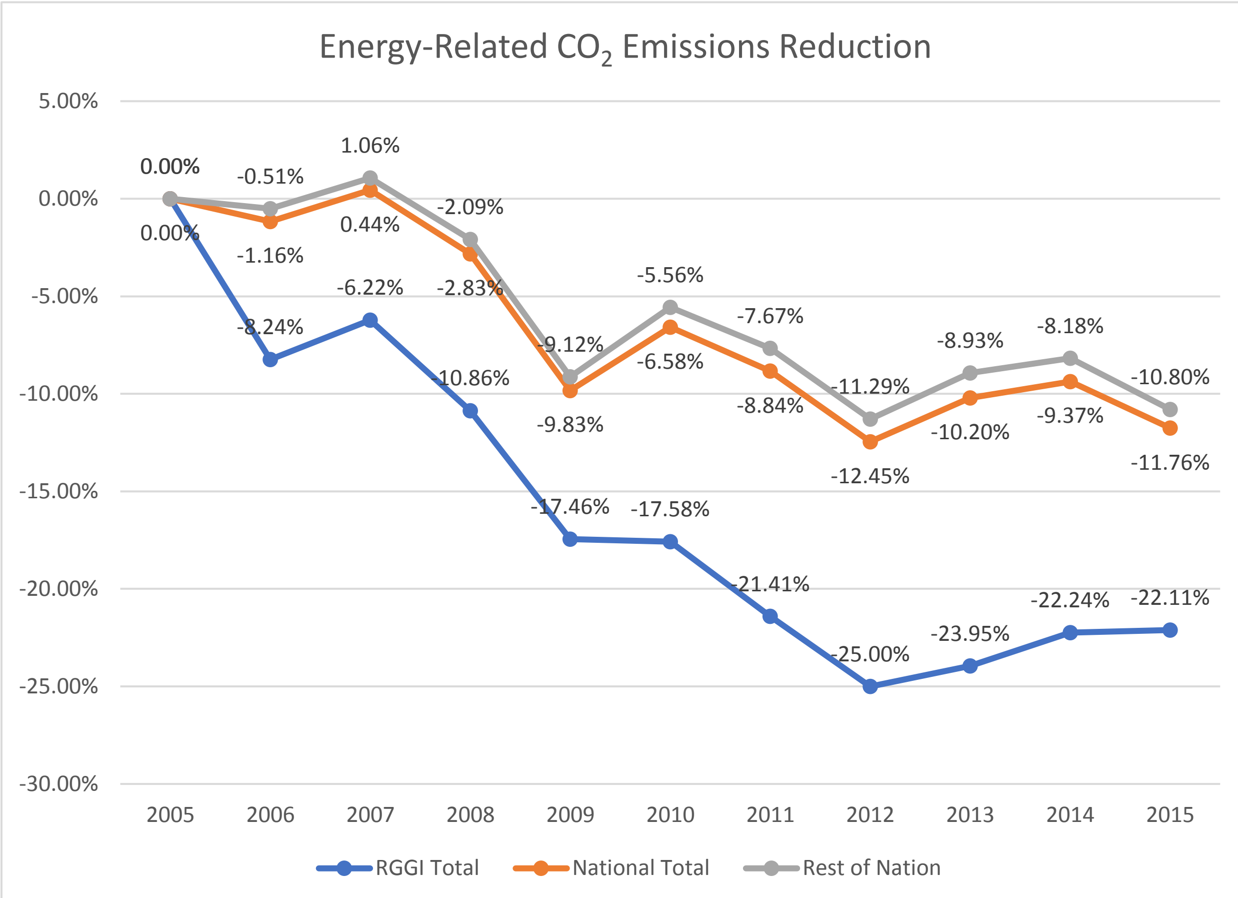

Figure 3 (See Appendix D for Data)
Data Source: U.S. EIA 2018a

Of the three renewable sources used in the RGGI region, Biomass is the most common, although that is changing. EIA data shows that in 2010, Biomass accounted for 71.6% of all renewable generation within RGGI. By 2013, that amount had decreased to 55.3%. In 2017, Biomass, for the first time, no longer consisted of the majority of renewable generation at 46.9%, the plurality of renewable generation within the region. Wind, as evidenced by its significant growth in output over the last 8 years, in 2017 accounted for 42.9% of total renewable generation (up from 28.4%), while solar increased from one tenth of one percent to 10.3% of total renewable generation in 2017 (U.S. EIA 2007-2018). Given the pattern of growth of wind energy in the region, and the lack of growth of biomass, wind is likely to surpass biomass as the primary source of renewable energy within the region by the year 2020.

Collectively, these changes to the generation portfolios within RGGI have facilitated a 22.1% decrease in greenhouse gas emissions from electric generation. This total far exceeds the remaining states in the nation (as shown in Figure 3), which only reduced their collective emissions by 10.8%, and the nation as a whole, which reduced its emissions by 11.8% (EIA 2018a). However, it should be noted that over that time period (2005-2015), RGGI states reduced total generation by 13.8%, contributing to the reduction of emissions, with the region seeing a 20.4% decrease in generation by 2017 (U.S. EIA 2007-2018). Emissions intensity (the amount of emissions per MWh of generation) also decreased during that decade, with emissions per MWh decreasing from 1.525 metric tons of CO2 per MWh (MT/MWh) to 1.378 MT/MWh, down 9.6%, indicating that any new generation that came online was ultimately cleaner than the generation it replaced (U.S. EIA 2007-2018; 2018a).

However, not all states within RGGI experienced similar success in improving their generation portfolio and reducing their emissions.

Connecticut

Since 2005, overall generation in the state of Connecticut has remained flat, with only a marginal decrease of 0.25% by 2017, while consumption decreased by 15.4%, leaving a generation surplus of roughly 5,200 GWh. Connecticut's portfolio has undergone significant changes since 2005, EIA data shows. Both coal- and petroleum-based generation has decreased by over 95% each (95.1% and 96.3% respectively), with most of that capacity moving to natural gas generation, which has increased by 67.9%. Additionally, generation from Connecticut's nuclear facilities has increased slightly, by about 6%, and the state's renewable generation increased by 22.1% (U.S. EIA 2007-2018). These changes in electric power generation helped Connecticut reduce its emissions by over 17%, which is higher than the national average, but lower than the RGGI total (U.S. EIA 2018a).

Delaware

Delaware is one of the smallest states in the nation, both in terms of population and geographic footprint. As such, it does not have a large amount of in-state power generation, as shown by EIA data. However, the state made significant strides in improving its generation portfolio. Since 2005, Delaware's total electricity generation has been trending slightly upward, although 2017 generation levels were lower than 2005 by over 1 million megawatt hours, or down 14.8%. Consumption decreased by 10%, slightly expanding the state's generation deficit. Most significantly, the sources of electricity generated within the state have drastically changed in 12 years. In 2005, all of Delaware's generation was produced by fossil fuels, with nearly two-thirds generated by coal. By 2017, the state had managed to reduce its reliance on coal to less than 6%, while nearly eliminating petroleum-based generation. While still heavily reliant on fossil generation, 92.4% of the state's generation portfolio is now powered by cleaner natural gas, and the state has added over 100,000 megawatt hours of renewable generation to its portfolio (U.S. EIA 2007-2018). This has helped the state reduce its emissions by 23%, slightly ahead of the RGGI total (U.S. EIA 2018a).

Maine

Maine is one of two RGGI states where renewables (including hydroelectricity) power the majority of its generation portfolio, according to data from the EIA. In 2005, the majority of the state's generation (51.3%) came from natural gas, while 39.6% came from hydro and renewables combined. Over the last 12 years, Maine has substantially reduced its reliance on coal and petroleum for generation, with each now accounting for less than two percent of total generation. Additionally, generation from natural gas was cut by 76%, and natural gas now accounts for about 19% of the state's generation portfolio. Maine has also significantly increased its generation from non-hydro renewable sources, nearly doubling the electricity generated by renewable sources, increasing renewable generation from 14.6% to 44.1% of the state's generation. Combined with hydroelectricity, renewables account for 77.1% of the state's portfolio. However, the large renewable footprint results in part from a substantial reduction in overall generation in the state (U.S. EIA 2007-2018). Overall generation within the state decreased by 35.3%, while consumption declined by only 7.7%, with a slight generation surplus in 2005 becoming a generation deficit of over 2,400 GWh, requiring imported generation to cover the difference. Over two thirds of the lost fossil generation was not replaced with new in-state generation, instead being imported from Canada (U.S. EIA 2007-2018; ISO-NE n.d., "Resource Mix"; National Energy Board 2018b). These changes to the state's energy portfolio have helped reduce the state's emissions by 27.3%, the third highest improvement within RGGI (U.S. EIA 2018a).

Maryland

Maryland generates the second highest amount of electricity of the current RGGI states, behind only New York, according to EIA data. Like most RGGI states, Maryland saw a substantial reduction in the amount of electricity generated by its power plants, decreasing power generated by over one third from 2005 to 2017. At the same time, the state only saw a

13.4% decrease in consumption, resulting in a 58% increase in the state's generation deficit from 16,346 GWh to 25,823 GWh, requiring increased imports. During that period, the state saw a substantial shift in its generation portfolio. In 2005, the majority of electricity generated in Maryland came from coal plants (55.8%), with nuclear being the second largest source, accounting for 28.3% of the state's generation, and other sources accounting for the rest, with only petroleum accounting for more than five percent (7.2%). By 2017, the state had substantially reduced its fossil fuel generation. Coal generation over that time decreased by 71%, while petroleum has nearly disappeared, accounting for only one third of a percent of the state's generation portfolio. Offsetting some of those losses, the state dramatically increased its generation from natural gas, increasing output from the source by 237%. The state also saw a significant increase in renewable generation, increasing by 233.2%. Maryland even saw a slight increase from its Calvert Cliffs nuclear facility, which became the largest source of power generation in the state, accounting for 45.3% of total generation (U.S. EIA 2007-2018). The substantial reductions and shifts in Maryland's energy portfolio have helped the state reduce emissions by 28.7%, well ahead of the nation, and the second highest improvement among the RGGI states (U.S. EIA 2018a).

Massachusetts

Massachusetts is an interesting case study, in that it reduced its emissions almost entirely through fossil reduction than through additions in renewable generation, as shown in EIA data reports. In 2005. fossil-based sources accounted for 82.7% of the electricity generated in the state, over half of which was natural gas. Since then, use of coal and petroleum generation in the state has been drastically reduced, by 90.5% and 96.7% respectively, to the point where they collectively account for less than 5% of the total generation in the state. While there was minimal increase in natural gas-based generation, due to portfolio rebalancing it now accounts for 67.3% of total generation, as the state did not add sufficient renewables to its portfolio to replace the lost fossil generation. Renewable generation nearly doubled during that timeframe, a substantial improvement, but behind other RGGI states on a percentage-basis. Total generation in the state decreased by 34.3% during this period, while consumption remained relatively flat, trending downward despite a noticeable increase in consumption from 2016 to 2017, ultimately widening the generation deficit within the state, requiring more imported electricity. (U.S. EIA 2007-2018). Through their substantial reduction in fossil-based generation, Massachusetts managed to reduce its emissions by 22.4%, slightly ahead of the RGGI total and well ahead of the rest of the nation (U.S. EIA 2018a).

New Hampshire

Like several other RGGI states, New Hampshire was heavily reliant on fossil generation prior to the program's start according to EIA data, with fossils combining to collectively generate just under half of the state's portfolio (49.7%). However, it is one of only a few RGGI states to maintain a heavy reliance on nuclear generation. In both 2005 and 2017, nuclear was the largest source of electric generation within the state. New Hampshire's generators have substantially reduced their use of fossil fuels, reducing the use of coal and petroleum by almost 93% each (down to about 1.7% and 0.5% respectively), and even reducing the use of natural gas by almost half (about 46.5%). As a result, combined with a nearly 6% increase in nuclear output, nuclear power in 2017 accounted for 57.4% of total generation within the state (up from 39.3%), while natural gas accounted for 20.4%, down from 27.5% of total generation, and hydroelectricity accounted for about 7.4% of the state's portfolio in both 2005 and 2017. The state also saw a significant increase in renewable generation, more than doubling output between 2005 and 2017 (up 162.8%), making non-hydro renewables currently the third largest source of generation in the state, at about 12.4%. Total generation in New Hampshire decreased by 27.8% from 2005 to 2017, while consumption also decreased by about 500 GWh to 10,750 GWh, resulting in a nearly 50% reduction in the state's generation surplus (U.S. EIA 2007-2018). These changes to the state's generation portfolio resulted in New Hampshire decreasing its energy-related emissions by 29.1%, well above the rest of the country, and the highest emissions reduction among all RGGI states (U.S. EIA 2018a).

New York

New York State holds the distinction of having the lowest energy use per capita of any state in the nation, at 189M BTUs per capita in 2015 (U.S. EIA n.d.). This is reflected in both the state's energy portfolio data and its annualized emissions data. From 2005 to 2017, New York reduced its total power generation by nearly 13.1%, according to data from the EIA, while consumption only decreased slightly, resulting the state's generation deficit more than tripling, increasing import requirements. More importantly, however, the state dramatically reduced its use of less efficient fossil fuel generation, decreasing coal- and petroleum-based power generation by over 97% each, replacing much of that generation with cleaner-burning natural gas and environmentally friendly renewable energy (U.S. EIA 2007-2018). Over the same time period, New York increased natural gas generation by 51.1%. Most significantly, the state increased its generation from non-hydro renewable sources by 271.2%. While non-hydro renewables only account for about 5% of total generation in the state, the increase over that time period is still significant. The state now generates almost 94% of its electricity through natural gas, nuclear and hydro. This is a substantial increase for these three sources from 2005, when they combined to account for only about 68% of total generation (U.S. EIA 2007-2018). This shift in generating capacity from older fossil sources to newer and cleaner sources resulted in a decrease in emissions of 20.5% from 2005 to 2015 (U.S. EIA 2018a).

Rhode Island

Rhode Island, like Delaware, has a small geographic footprint, and similarly does not generate much electricity within its borders according to EIA data, and the electricity it does generate almost entirely comes from cleaner sources. In 2005, 99.8% of electricity generated in Rhode Island came from natural gas plants, with the rest generated by petroleum. Because natural gas is a cleaner source than other fossil fuels, all of Rhode Island's subsequent improvement came from increasing renewable generation. By 2017, the state had added 369,000 megawatt hours of renewable generation, now accounting for over 7% of total generation in the state. Generation from petroleum sources remains minimal, accounting for less than one percent of total generation. The remaining amount, 92%, continues to be generated from natural gas, with overall generation decreasing by 13.3% since 2005. Similar to Delaware, the state consumes more electricity than it generates, by over 2,000 GWh, requiring imports from neighboring states (U.S. EIA 2007-2018). While Rhode Island substantially increased its renewable generation during that time period, the state did not substantially reduce its emissions from 2005 to 2015, in part because the vast majority of the state's generation portfolio continues to be derived from natural gas. Over the course of the decade, the state managed to reduce energy related emissions by only 2.68%, by far the smallest improvement among RGGI states (U.S. EIA 2018a). While Rhode Island's emissions reduction was minor, the state's energy portfolio is clearly headed in the direction of increased renewables.

Vermont

Vermont is the other state where renewables (including hydro) account for the majority of the state's energy portfolio, according to the EIA. Vermont's use of renewables is so pervasive that it accounts for almost 100% of the electricity generated within the state, with a small amount coming from petroleum and natural gas (U.S. EIA 2018). In 2005, the state generated the majority of its electricity by nuclear power from the since shuttered Vermont Yankee plant (U.S. EIA 2007; ISO-NE n.d., "Resource Mix"). While Vermont is now virtually all renewable, it was able to achieve that feat by reducing its total generation by over 60% from 2005. As such, consumption now vastly outpaced generation within the state (5,392 GWh vs. 2,073 GWh), requiring the state to import the majority of its energy needs from bordering states and Canadian provinces, both of which have substantial hydroelectric and renewable generation (ISO-NE "Resource Mix"; National Energy Board 2018C; U.S. EIA 2007-2018). During that time, the state was able to more than double its generation from non-hydro renewables, now accounting for 41.3% of total generation (up from 7.3%), with most of the remainder coming from hydropower (U.S. EIA 2007-2018). In 2005 and 2015, Vermont was the lowest emitting state in RGGI. These changes helped the state reduce emissions by 10.3%, despite limited room for improvement (U.S. EIA 2018a).

New Jersey

One interesting point of comparison is a state that left RGGI after only a few years. New Jersey was a founding member of the Initiative and was a major participant during its first few years. However, in 2011, then-Governor Chris Christie, a Republican, unilaterally decided to remove the state from RGGI (Bifera 2013, 3). In early 2018, current Governor Phil Murphy, a progressive Democrat, issued a memorandum to begin the process of rejoining RGGI (McKenna 2018). While New Jersey has not yet rejoined the Initiative, because it was a member for several years, the state's data remains relevant with respect to RGGI, and will be examined despite its fluctuating status.

As New Jersey exited the Initiative early, its progress in lowering emissions and improving its energy portfolio was understandably stunted. From 2005 to 2015, New Jersey reduced its emissions by just over 14%, according to the EIA. This amount is slightly ahead of the national average of just under 12%, although it falls short of the RGGI combined greenhouse gas reduction of 22.1% (EIA 2018a). However, the state made notable progress in changing the state's energy portfolio. From 2005 to 2017, New Jersey reduced its coal generation, which previously accounted for nearly 20% of the state's generation, by nearly 90%. The state also increased its natural gas generation by nearly 150%, which combined with nuclear generation, accounts for nearly 95% of the state's energy generation. However, the state's total generation increased by over 23% from 2005 to 2017, the opposite of the trend seen in RGGI states. Additionally, the state's renewable sector remains fairly small, accounting for less than 2.5% of total generation, although it has been increasing, and the likely recommitment to RGGI bodes well for the future of renewables in the state (U.S. EIA 2007-2018).

Comparisons

While the RGGI states compared favorably to the remainder of the nation, it is also useful to examine how the program compares to other emissions control programs elsewhere in the world. Two examples that provide useful comparisons of emissions reduction to RGGI are the European Union Emissions Trading System and the British Columbia Carbon Tax.

European Union Emissions Trading System

The European Union's Emissions Trading System was the world's first major cap-and-trade system for greenhouse gas emissions. Created in part to comply with Europe's obligations under the Kyoto Protocol, the EU ETS began operation in 2005. It currently encompasses 31 countries, and in addition to carbon dioxide, also covers emissions of nitrous oxide and perfluorocarbons. The program has emissions goals of 21% reduction in emissions from covered sectors (except aviation) by 2020 (over 2005 levels), and a goal of 43% emissions reduction by 2030 (over 2005 levels) (European Commission 2016; Brown et al. 2012, 4-5).

Over the last 13 years, the EU ETS has evolved to become one of the most comprehensive carbon control programs in the world. While the EU ETS started with limited sector involvement, it has since expanded to cover additional sectors and subsectors, including the aviation sector. Additionally, the program adapted its allocation system to combat overallocation and market volatility, gradually incorporating an auction-based allocation system, and adding allowance banking and borrowing across program phases. (European Commission 2016; Brown et al. 2012).

The EU Emissions Trading System generated emissions reductions on par to those of RGGI. Nominally, the EU reduced its emissions by 10.5% from 2005 to 2015, using only the emissions covered for each year. However, when adjusting for the addition of new industrial and transportation sources, and incorporating those emissions into totals for all years, the EU reduced its emissions by 24%, slightly ahead of RGGI over the same time period (European Environment Agency 2017).

British Columbia Carbon Tax

Cap-and-trade programs are not the only policy method for reducing greenhouse gas emissions. The same effect can also be achieved by using a carbon tax. While a cap-and-trade system creates a hard carbon target, allowing participants to buy, sell, or trade allowances to get under the limit, a carbon tax sets a hard price for carbon, with both reducing emissions by increasing the marginal cost of emitting (Frank 2014). One such example is in British Columbia, Canada. In 2008, the provincial government implemented a carbon tax policy, covering 70% of all greenhouse gases emitted within the province, with the caveat that the funds raised through the tax would be returned to the people in the form of reduced taxes, making the system revenue neutral (Province of British Columbia n.d.).

The carbon tax program has had some success in reducing emissions, although it has not experienced the same level of success at reducing greenhouse gas emissions as the larger RGGI and EU Emissions Trading System. British Columbia generates the vast majority of its electricity through renewable sources, particularly hydroelectricity, and as a result, power generation in the province only accounts for 1-2% of its total greenhouse gas emissions (Province of British Columbia 2017; National Energy Board 2018a). When looking across all sectors, over the same time period of 2005-2015, British Columbia only reduced its carbon emissions by around 5%. Interestingly, if the emissions reduction was calculated from the year of the carbon tax's inception, then economy-wide emissions reduction declines to 2.1% (Province of British Columbia 2017).

Starting out at $10 CDN per metric ton, the carbon tax gradually increased over its first few years, reaching its current level of $30 CDN per metric ton (Province of British Columbia n.d.). Compared to the auction prices in the EU and RGGI, this amount initially appears noticeably higher. However, when adjusted for currency and metric conversion, the carbon prices are closer. Using the currency conversion rate on April 29, 2018, the carbon tax is equal to $23.39 USD per metric ton (XE.com 2018). Adjusting for the difference between metric tons and short tons, the tax comes out to an equivalent of $21.22 USD per short ton. This amount is vastly higher than current auction prices in RGGI and is nearly three times the peak price of $7.50 (RGGI, Inc. n.d., "Allowance Prices and Volumes"). However, the auction prices in the EU ETS are generally higher than they are in RGGI, with an average auction price for April 2018 of €13.22[4] (EEX 2018), which converts to $16.04 USD[5] (XE.com 2018a). When adjusted for short tons, the price is $14.55 per short ton, meaning that the EU auction prices roughly split the difference between the RGGI auction and the British Columbia carbon tax. One would think that the higher cost of carbon would result in lower emissions. However, given the tax's

[4] As of April 29, 2018.
[5] Using currency conversion rate on April 29, 2018.

revenue-neutral nature, it is possible that the resulting lower taxes may be having a counteracting effect on the tax itself.

One major strength that BC's carbon tax has over RGGI is that it encompasses a broader cross-section of the economy, in part by focusing on fuels rather than generation. RGGI, as noted earlier, only covers power generation, and while the European Union system is broader (covering 45% of greenhouse gas emissions), they do not currently cover the same scope of emissions as BC's system (European Commission 2016; RGGI, Inc. n.d., "Elements of RGGI"). California's newer emissions trading system, which works in tandem with other Canadian provinces, covers 85% of all greenhouse gas emissions in the state (C2ES n.d., "California Cap and Trade"). However, the carbon tax has one major flaw in its design. Because there is no associated cap, emissions under a carbon tax can vary more from year to year, which can become problematic if a municipality is trying to reach a specific goal (Frank 2014).

External Factors

While the goal of RGGI has been to reduce greenhouse gas emissions among the member states, there are a few additional factors that likely had an effect on emissions reduction and the changes in the region's generation portfolio.

Cost of Energy

The cost of energy is an important factor in deciding what kind of generation to implement in an area. The unsubsidized costs in the United States, over the last decade, have been increasingly favoring renewables and more efficient forms of energy generation, according to Lazard, which annually release a report on the levelized cost of energy. In 2009, utility-scale solar photovoltaic (PV) was prohibitively expensive at over $350/MWh. The remaining forms of energy cost between $80 and $140/MWh, with wind being the highest among those at $135/MWh, and natural gas combined cycle being the lowest at $83/MWh. By 2017, the cost landscape had radically changed. The costs of wind and solar PV energy had fallen so significantly that they surpassed natural gas as having the two lowest levelized costs of energy at $45 and $50/MWh respectively, although natural gas was not far behind at $60/MWh. This cluster of wind, solar and natural gas at lower price point makes them comparatively more palatable to electric utilities and generators than coal, which costs 70% more per MWh than natural gas, and nuclear, which at $148/MWh might require government subsidies simply to keep existing plants open (Lazard 2017, 2-3; 2017a). It should be noted, however, that energy prices in the northeastern United States tend to be higher than the nation as a whole, with all states in RGGI having higher electricity prices in 2017 that the national average, ranging from $10.99 to $17.62 per KWh compared to the national average of $10.54 per KWh (U.S. EIA 2018). Offshore wind, which several RGGI states are considering, is priced separately by Lazard from land-based wind turbines, having a higher levelized cost at $113/MWh, which could be made more palatable to utilities through subsidies (Lazard 2017, 2-3).

Renewable Portfolio Standards

RGGI is limited in its coverage of generation sources, only requiring fossil-fuel generators with a nameplate capacity of 25MW or greater to purchase carbon allowances to cover their emissions. Renewables are not required to purchase carbon allowances, as they emit no carbon dioxide. Along the same lines, in its effort to reduce emissions, RGGI has no specific requirement regarding the implementation of renewable sources (Bifera 2013, 5-7; RGGI, Inc. n.d., "Elements of RGGI"). While cleaner sources like renewables are likely to be adopted by states when facing a carbon cap, if there is no specific requirement, it would hypothetically make the most sense for utilities to use the lowest cost option.

Instead, many states, including all RGGI states, have Renewable Portfolio Standards, which are designed to spur investment in renewable generation within the state, with set goals for increasing renewables in the state's portfolio. A Renewable Portfolio Standard (RPS), also known as a Renewable Electricity Standard, is a state-level program setting mandatory (or in some cases, voluntary) renewable generation goals within the state, often with carve-outs for specific forms of renewable generation like solar or offshore wind. It is this mandate that makes the RPS a more likely instigator of investment and development of renewable generation with the RGGI states. Renewable Energy Certificates (RECs) are often used in RPS programs for trade and compliance purposes. A REC is created to certify the generation of a specific amount of renewable energy, and these RECs can also be traded among entities. However, many RPS programs offer alternative mechanisms to comply with the mandate, including offsets and alternative compliance payments, potentially reducing the overall impact of the RPS (NREL n.d., "Renewable Portfolio Standards"; U.S. EPA 2015; DSIRE 2017c; Durkay 2017).

While all of the states participating in RGGI have an RPS program in place, many of them have very ambitious renewable goals. Overall, the RPS programs in RGGI have renewable goals varying from 15% to 50%, with target dates ranging from 2017 to 2035. Most programs have carveout requirements for specific forms of renewable generation (such as solar or offshore wind), and most incorporate RECs as a compliance mechanism, while all have alternative compliance payment mechanisms. Vermont has the most ambitious RPS in RGGI, with goals of 55% renewables by 2017 (which they achieved, as noted above), increasing to 75% by 2032. New York also has an incredibly ambitious RPS, given its size, with a goal of 50% renewables by the year 2030. Maine and Rhode Island both have high RPS goals, with Maine reaching their RPS goal of 40% by 2017, and Rhode Island aiming for 38.5% renewables by 2035, the latest target date in the region. Massachusetts has an escalating goal of an additional 1% per year after it reaches its primary goal of 20.5% by 2020. In 2017, Maryland's state legislature passed legislation to strengthen the state's RPS program, increasing the goal to 25%, while moving the goal up to 2020, while simultaneously adding a carve-out for offshore wind, in addition to the program's pre-existing carve-out for solar. The remaining three states (Connecticut, Delaware, and New Hampshire) have set similar RPS goals, with Connecticut targeting 28% renewables by 2020, Delaware targeting 25% by 2025-2026, and New Hampshire targeting 25.2% by 2025, with each containing carveouts for specific technologies (DSIRE 2016; 2016a; 2017; 2017a; 2017b; 2017c; 2017d; 2017e; 2017f).

Emissions Leakage

Emissions leakage is one of the major flaws of the program. As observed in EIA data, most of the RGGI states decreased their total in-state generation from 2005 to 2017. However, consumption of electricity has changed little and remains higher than total generation within the region, meaning more electricity is being imported from out-of-state (U.S. EIA 2007-2018). Consider the example of the New England states. All RGGI members, together they form the service area for a single independent system operator, ISO New England. From 2005 to 2015, the region reduced its greenhouse gas emissions by nearly 21%, far exceeding most other states and the nation as a whole (U.S. EIA 2018a). New England did this, in part, by making major changes to its generation portfolio, increasing renewable generation, and switching from coal and petroleum to cleaner sources. From 2005 to 2017, New England states reduced generation from coal and petroleum by over 90% each (91.7% and 95.1% respectively), while more than doubling renewable generation within the region (up 103.5%) (U.S. EIA 2007-2018).

However, the changes to the region's energy portfolio resulted in a noticeable decrease in the amount of electricity generated within the states. In 2005, according to ISO New England, the New England states collectively generated 131,877 GWh of electricity. By 2017, that amount had dropped 22.3% to 102,534 GWh (ISO-NE n.d. "Resource Mix'; ISO-NE 2017). ISO New England also noted that energy consumption within the region was declining, dropping to 121,061 GWh in 2017 from a peak of 136,355 GWh in 2005, a decline of 11.2% (ISO-NE n.d., "Electricity Use"). This discrepancy meant that New England was importing electricity from elsewhere to meet their total energy demand.

According to ISO New England, in 2017, the System Operator imported 20,243 GWh of electricity from neighboring regions, a total of 16.7% of energy consumed. This included 1,536 GWh from New York. However, most of their imported power originated from Canada (ISO-NE n.d. "Resource Mix"). Maine received 4,306 GWh from New Brunswick, while the vast majority of the imports, 14,401 GWh, came from the province of Quebec (ISO-NE n.d., "Resource Mix"; National Energy Board 2018b).

This is where the program flaw exists. Imports are not covered sources under RGGI, just fossil generation within participating states' borders. This is potentially a giant loophole in the program, and as participating states decrease their fossil generation, they are increasingly relying on imported generation (Ramseur 2017, 14; Tietenberg 2013, 319-320; RGGI, Inc. 2016, 10-11). In the case of New England, the vast majority of their imported generation is likely renewable. Both New York and Quebec are heavily reliant on Hydroelectricity and other renewable sources, with hydro accounting for 22.7% in New York and 95% in Quebec, and other renewables accounting for 4.8% in New York and 4% in Quebec (U.S. EIA 2018; National Energy Board 2018c). Both of these regions also participate in greenhouse gas cap-and-trade programs, with New York being a founding member of RGGI, and Quebec having their own program, which is linked to California's new program (RGGI, Inc. n.d., "Program Design Archive"; C2ES n.d., "California Cap and Trade").

New Brunswick, however, is a different story. While imports from the province are minimal, and only apply to one state, their energy portfolio is not nearly as clean as its neighboring states and provinces. While roughly 30% percent of New Brunswick's generation comes from hydro and renewable sources (including wind and biomass), and another 30% comes from nuclear generation, the remaining 40% comes from older fossil sources (National Energy Board 2018b). This is a problem, because it makes it more difficult to trace the source of the imported energy. When a state or province is generating 90%+ of their power from renewables, tracing the source is a much more clear-cut task.

Using overall emissions intensity, combined with generation totals, will provide a total emissions footprint. Accordingly, the emissions intensity associated from New Brunswick imports fluctuated wildly from 2005 to 2012, before leveling off at 639 lbs. CO_2/MWh (or 0.3195 short tons/MWh) in 2013 and 2014. Assuming similar numbers in 2017, then the 4,306 GWh in imported generation from New Brunswick would result in 1,375,767 tons CO2/MWh.

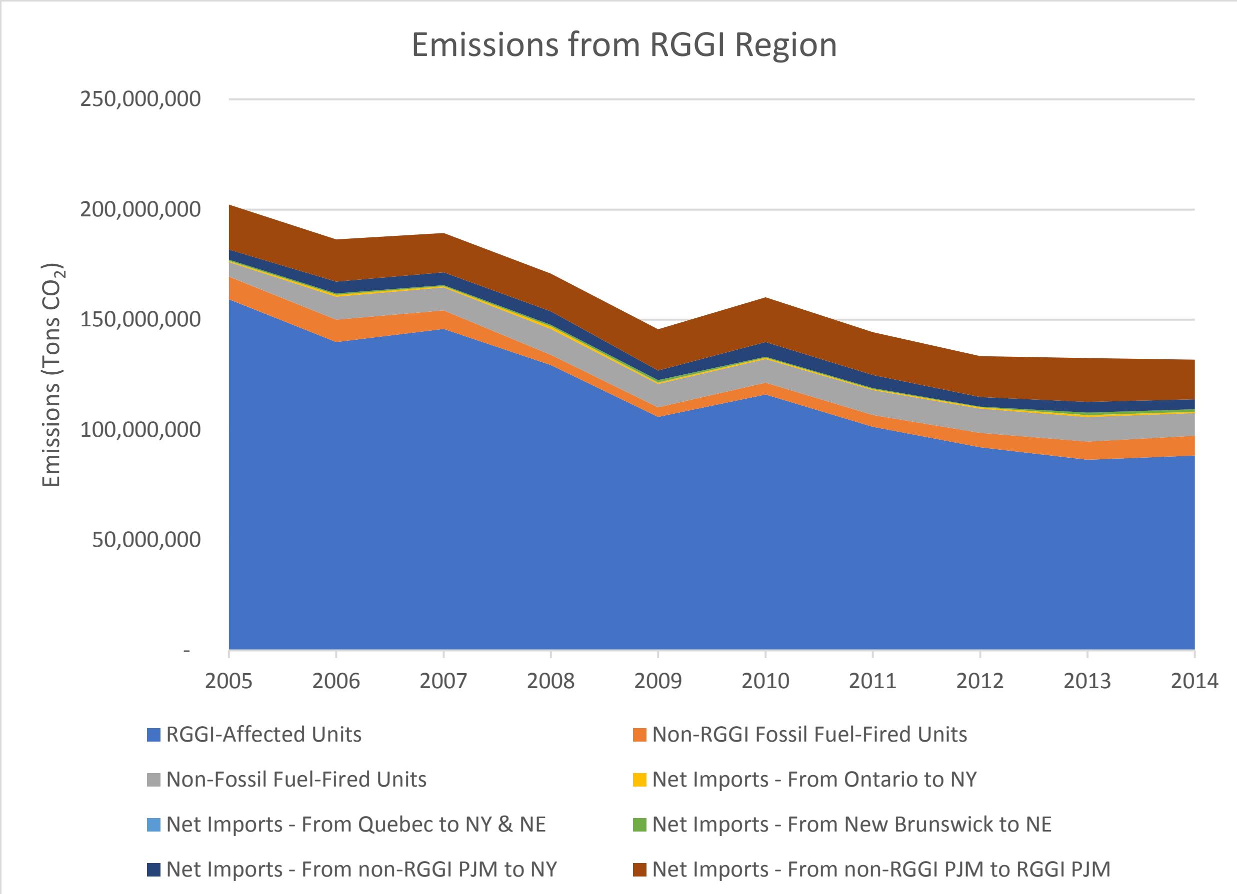

Figure 4 (See Appendix E for Data)
Data Source: RGGI Inc. 2016

Comparatively, Quebec had an emissions intensity of 4 lbs. CO_2/MWh (or 0.002 short tons/MWh) in 2013 and 2014. When applied to its 2017 imports of 14,401 GWh, total carbon emissions from Quebec equal only 28,802 tons CO_2/MWh, just over one fifth of the emissions footprint of New Brunswick, despite exporting more than three times the amount of electricity to the RGGI region. (RGGI, Inc. 2016, 15).

The issue of emissions leakage is prevalent throughout the RGGI region. The chart in Figure 4 shows combined 2005-2014 CO_2 emissions of the RGGI states including emissions from in-state generation as well as those from imported generation according to data compiled by RGGI for its 2014 Monitoring Report. Overall emissions in the region decreased over the timeframe by 27.5%. Emissions from RGGI-affected units clearly and substantially decreased over the decade, decreasing by 44.5% from 2005 to 2014. However, emissions from other, non-affected sources have not changed nearly as significantly. Emissions from imported sources only decreased by 6.9% over that time period, and due to the substantial reduction from RGGI-affected sources, imported emissions account for a larger percentage of total emissions, up to 18.4% from 14.3% (RGGI, Inc. 2016, 15).

The remaining states within RGGI have potentially larger issues with emissions leakage due to imports from the neighboring PJM independent system operator. New York imports generation from Ontario, Quebec and PJM states (given the proximity, most likely Pennsylvania and New Jersey). In 2014, the state imported 7,180,281 MWh of generation from Ontario, 8,839,775 MWh from Quebec, and 8,239,526 MWh of generation from PJM. Over the decade, imports from Ontario and Quebec trended upward while imports from PJM maintained a relatively flat trend. Although the imports are similar in amount, their carbon footprints are vastly different due to the emissions intensity of generation from each region. Ontario generation has an emissions intensity of 168 lbs. CO2/MWh (or 0.084 tons/MWh) and Quebec has a previously mentioned intensity of 4 lbs. CO2/MWh, while PJM generation imported into New York has a substantially higher emissions intensity of 1,101 lbs. CO2/MWh (or 0.5505 tons/MWh). As a result, PJM imports to New York produce 4,534,250 tons of CO2 while Ontario and Quebec imports only produce 603,144 tons and 19,488 tons of CO2 respectively, each a fraction of the emissions from PJM, which alone accounted for 3.4% of total RGGI emissions in 2014 (RGGI, Inc. 2016, 15, 32-33).

Maryland and Delaware import all of their outside generation from PJM, and as such, their exposure to emissions leakage is much more substantial. In 2014, the two states (which are members of both RGGI and PJM) imported a total of 32,656,507 MWh of generation from other states in PJM (likely Pennsylvania, New Jersey and West Virginia).[6] While it is a negligible increase over 2005, imports from PJM were trending upward over the decade. Given the previously mentioned emissions intensity, imports from other PJM states produced 17,971,031 tons of CO2, an amount greater than the emissions from all other imports into the RGGI region combined. As can be seen in Figure 4, while RGGI-affected emissions decreased substantially over the decade, PJM to PJM imports remained fairly consistent, and clearly make up an increasingly sizable percentage of emissions. Just these imports alone produce 13.6% of the CO2 emissions in the RGGI region, the second largest amount in RGGI (RGGI, Inc. 2016, 15).

Success or Failure?

Successes

The Regional Greenhouse Gas Initiative overall has seen some success in improving emissions and reducing the region's reliance on fossil fuels for electricity generation. Overall the participating states exceed the nation in terms of emissions reduction, and was on par with other emissions control programs, specifically the EU Emissions Trading System. While many of the factors that might have affected RGGI's emissions reduction, such as the cost of energy and renewable portfolio standards, were present elsewhere in the nation, the RGGI states

[6] The RGGI Monitoring Report does not separate imports by Maryland and Delaware, categorizing them collectively as "RGGI PJM."

collectively managed to exceed the nation in emissions reduction, despite running behind the nation in implementing renewable energy (U.S. EIA 2007-2018; 2018a).

One of the major successes of RGGI is that it has generated substantial economic benefit for the region. In a report released in April 2018, Analysis Group found that during RGGI's third control period, from 2015 to 2017, the program generated a net economic advantage of $1.4 Billion for the region, while creating 14,500 job-years (one job over a 12-month period) (Hibbard et al. 2018, 4, 8-9). This economic benefit was generated primarily by allowance auction revenues, which the states use to fund programs that further the goals of RGGI, including energy efficiency programs and carbon sequestration projects (Hibbard et al. 2018, 4-5; RGGI, Inc. n.d. "About Auctions"). Roughly $1 Billion in revenue was generated from allowance auctions during the third control period, with a total of almost $2.8 Billion in revenue since 2009, when the program began (Hibbard et al. 2018, 2, 4).

As noted earlier, the Initiative also contributed to substantial changes in the region's energy portfolio. Capping the emissions carbon dioxide, combined with the decreasing price of renewables and mandated renewable generation goals, RGGI helped to usher in noticeable increases in renewable generation within the region. Additionally, RGGI's policies helped to foster a major shift from older fossil generation, such as coal and petroleum, to more efficient natural gas-based generation (RGGI, Inc. "Elements of RGGI"; U.S. EIA 2007-2018; Lazard 2017a; NREL n.d. "Renewable Portfolio Standards"). While RPS were likely the primary initiator of increases in renewable generation, given that renewable energy sources account for a smaller percentage of generation than the nation as a whole (U.S. EIA 2007-2018), it is likely that RGGI is a primary instigator of the generation changes and emissions reduction within the region.

Failures

While the Initiative was generally a success, it was not without its failures. As noted earlier, the decrease in generation within the region is creating an increasing disparity with consumption within the region, requiring more imported electricity, and leaving the program vulnerable to emissions leakage (U.S. EIA 2007-2018; RGGI, Inc. 2016, 15).

The surplus of allowances is a significant flaw in RGGI's design. This flaw occurred when RGGI overallocated the amount of carbon allowances in early auctions. A number of factors, including lower demand and a shifting portfolio resulted an excess of allowances being allocated. Carbon allowances in RGGI do not expire, so participating entities can hold on to them indefinitely. Entities could then go on to "bank" their allowances and use them for later years when they might have otherwise fallen short, effectively reducing the overall emissions improvement (Bifera 2013, 5; Ramseur 2017, 8-10).

Despite the initial surplus, allowance banking is not necessarily a flaw itself. While a banking system could result in a surplus of allowances, potentially affecting overall emissions, allowing banking of carbon allowances provides greater flexibility for the participants in terms of planning for future years or in the event of a poor year emissions-wise. For example, when the EU Emissions Trading System added cross-phase banking, it helped to stabilize the auction price of carbon allowances. (Brown et al. 2012, 17-19).

The banking of allowances across compliance periods could potentially be useful, encouraging participating entities to take corrective action now, and bank allowances for later years when the cap's lower allowance supply results in higher prices. However, banking is ideally combined with a robust cap (Brown et al. 2012, 17-19). In the early years of RGGI, the cap was set between 165 million tons and 188 million tons of CO_2, and for several auctions during that period, the clearing price for allowances fell to the price floor and not all allowances were sold. However, RGGI did ultimately take corrective actions under the second model rule. When the cap was reduced to 91 million in 2014, the substantial reduction helped to offset the outstanding allowance surplus, and the lower supply caused the clearing price for allowances to increase significantly as high $7.50 in the third control period. Although the price has since fallen to near $3.00, it has not fallen to the price floor level since, and all allowances were sold at recent auctions (Ramseur 2017, 10-11).

In these highly partisan times, particularly regarding issues pertaining to the environment and climate change, there is the potential for government apathy, whereby a legislature or governor lacks interest in the program and its goals, potentially resulting in scenarios where states join and leave depending on the political parties in power. The prime example of this is the state of New Jersey, which as noted above, was pulled out of RGGI by Governor Chris Christie for likely-partisan reasons (Bifera 2013, 3). Although they are now in the process of rejoining (McKenna 2018), the ability of a state to remove itself from the initiative should not be so simple. This is a flaw that could easily be addressed by updating the governing documents, requiring states to codify their emissions programs through legislation rather than regulation (which are both currently acceptable under RGGI) (RGGI, Inc. n.d. "Elements of RGGI"), and subsequently requiring states to get approval from both the legislature and executive before they can leave the Program.

Finally, biomass is a potential problem for RGGI due to its debatable status as a renewable. The federal government considers biomass to be a renewable source of energy, and it subsequently is not covered by RGGI (U.S. EIA 2018; RGGI, Inc. n.d. "Elements of RGGI"). However, as noted earlier, biomass is burned in order to generate electricity, emitting carbon dioxide and other potential pollutants in the process. The theory is that the replanted feed stock (trees or plants), will absorb enough carbon dioxide to fully offset the emissions from burning biomass. While grass and smaller plants can regrow fairly quickly, trees can take decades to regrow, meaning that those carbon emissions might not be fully offset for several years, all while additional biomass is being burned (NREL n.d. "Biomass Energy Basics"). Since biomass is currently the most prominent source of renewable energy within RGGI (U.S. EIA 2018), this could be a problem. As such, both RGGI and the federal government should consider the long-term recategorization of biomass as a renewable, removing select sources of biomass from the category and updating future Initiative model rules to reflect this.

Potential Improvements

There are a few potential improvements that could be made to RGGI in an effort to strengthen the program and ultimately improve emissions reduction. First, RGGI states should consider expanding the Initiative's coverage beyond large-scale fossil generation. Since RGGI's founding, other programs, including the EU ETS, the BC carbon tax, and California's new emissions trading system, have incorporated sectors outside of simple electric generation (European Commission 2016; Province of British Columbia n.d.; C2ES "California Cap and Trade"). Incorporating emissions from industrial facilities (and possibly commercial facilities) would be a good place to start, as industrial emissions are now covered by all three of the aforementioned programs. Implementing a method to cover the transportation sector, while more difficult, would be an admirable change to the program. Expanding coverage would bring the Program in line with its peers, and ultimately further decrease greenhouse gas emissions within the region.

Second, emissions leakage is a potential problem within RGGI, and creating a compliance mechanism to account for those emissions would minimize or eliminate one of the more prominent shortcomings of the program. This is not an easy task, as it involves both interstate and international electricity flow, and could potentially be a trade issue, resulting in litigation or the involvement of the World Trade Organization (Tietenberg 2013, 319-320). To limit this exposure, requiring the electric utilities that import generation from outside the region to account for and have allowances for the carbon emissions of those imports would be a potential starting point, while requiring all generators that sell within RGGI to have sufficient allowances would likely run into the noted legal problems. Implementing these changes would strengthen the program and accelerate the implementation of cleaner, renewable generation.

Acknowledgements

There are a few people I would like to acknowledge whose assistance, insight, and tutelage proved invaluable to this project. I first would like to thank Dr. Véronique Bugnion, Ph.D., Co-Founder and CEO of Clearly Energy and an Adjunct Professor at Johns Hopkins University, for acting as project mentor for this capstone project. This project benefitted immensely from her expertise on the subject matter. Her comments and input were invaluable. Additionally, I would like to thank Dr. Daniel Zachary, Ph.D., Program Director for the Energy Policy and Climate Program at Johns Hopkins University, for providing additional input and direction for the project, and for running a superb graduate program. Finally, though he was not involved in this project, I would like to thank Tom Tietenberg, Mitchell Family Professor of Economics, Emeritus at Colby College, for introducing me to the concept of cap-and-trade and the greater field of Environmental and Natural Resource Economics.

Bibliography

Bifera, Lucas. 2013. "Regional Greenhouse Gas Initiative." Arlington, VA: *Center for Climate and Energy Solutions.* Accessed March 23, 2018, https://www.c2es.org/site/assets/uploads/2013/12/rggi-brief.pdf.

Brown, Lucas Merrill, Alex Hanafi, and Annie Petsonk. 2012. "The EU Emissions Trading System: Results and Lessons Learned." New York: *Environmental Defense Fund*. Accessed April 15, 2018, https://www.edf.org/sites/default/files/EU_ETS_Lessons_Learned_Report_EDF.pdf.

Center for Climate and Energy Solutions. n.d. "California Cap and Trade." Accessed 20 December 2017, https://www.c2es.org/content/california-cap-and-trade/.

Center for Climate and Energy Solutions. n.d. "Regional Greenhouse Gas Initiative (RGGI)." Accessed 18 December, 2017, https://www.c2es.org/content/regional-greenhouse-gas-initiative-rggi/.

DSIRE. 2016. "Renewable Energy Portfolio Standard [Rhode Island]." Last modified June 29, 2016, accessed April 28, 2018, http://programs.dsireusa.org/system/program/detail/1095.

DSIRE. 2016a. "Renewable Energy Portfolio Standard [Vermont]." Last modified November 4, 2016, accessed February 9, 2018, http://programs.dsireusa.org/system/program/detail/5786.

DSIRE. 2017. "Renewable Energy Portfolio Standard [Connecticut]." Last modified November 2, 2017, accessed February 9, 2018, http://programs.dsireusa.org/system/program/detail/195.

DSIRE. 2017a. "Renewable Energy Portfolio Standard [Delaware]." Last modified July 13, 2017, accessed February 9, 2018, http://programs.dsireusa.org/system/program/detail/1231.

DSIRE. 2017b. "Renewable Energy Portfolio Standard [Maine]." Last modified August 8, 2017, accessed February 9, 2018, http://programs.dsireusa.org/system/program/detail/452.

DSIRE. 2017c. "Renewable Energy Portfolio Standard [Maryland]." Last modified September 13, 2017, accessed February 9, 2018, http://programs.dsireusa.org/system/program/detail/1085.

DSIRE. 2017d. "Renewable Energy Portfolio Standard [Massachusetts]." Last modified May 23, 2017, accessed February 9, 2018, http://programs.dsireusa.org/system/program/detail/479.

DSIRE. 2017e. “Renewable Energy Portfolio Standard [New Hampshire].” Last modified October 16, 2017, accessed February 9, 2018, http://programs.dsireusa.org/system/program/detail/2523.

DSIRE. 2017f. “Renewable Energy Portfolio Standard [New York].” Last modified December 14, 2017, accessed February 9, 2018, http://programs.dsireusa.org/system/program/detail/5883.

Durkay, Jocelyn. 2017. “State Renewable Portfolio Standards and Goals.” *National Conference of State Legislatures*, August 1. Accessed April 18, 2018, http://www.ncsl.org/research/energy/renewable-portfolio-standards.aspx.

European Commission. 2016. “The EU Emissions Trading System (EU ETS).” Accessed 20 December 2017, https://ec.europa.eu/clima/sites/clima/files/factsheet_ets_en.pdf.

European Energy Exchange AG. 2018. “EUA Primary Market Auction Report 2018.” [Excel Document] Accessed April 29, 2018, https://www.eex.com/public-data/emission-spot-primary-market-auction-report-2018-data.xls.

European Environment Agency. 2017. “EU Emissions Trading System (ETS) data viewer.” Last modified July 19, accessed February 25, 2018, https://www.eea.europa.eu/data-and-maps/dashboards/emissions-trading-viewer-1.

Frank, Charles. 2014. “Pricing Carbon: A Carbon Tax or Cap-And-Trade?” *The Brookings Institution*, August 12. Accessed April 23, 2018, https://www.brookings.edu/blog/planetpolicy/2014/08/12/pricing-carbon-a-carbon-tax-or-cap-and-trade/.

Hibbard, Paul J., Susan F. Tierney, Pavel G. Darling, and Sarah Cullinan. 2018. “The Economic Impacts of the Regional Greenhouse Gas Initiative on Nine Northeast and Mid-Atlantic States.” *Analysis Group*, April 17. Accessed April 18, 2018, http://www.analysisgroup.com/uploadedfiles/content/insights/publishing/analysis_group_rggi_report_april_2018.pdf.

Ho, Bruce and Morris, Jackson. 2017. "RGGI Agrees to Cut Power Plant Pollution by another 30." *Natural Resources Defense Council*., last modified Aug 23, accessed 19 December, 2017, https://www.nrdc.org/experts/bruce-ho/rggi-agrees-cut-power-plant-pollution-another-30.

ISO New England. 2017. “2000-2015 Net Energy and Peak Load by Source.” [Excel Document] Last modified February 28, 2017, accessed April 23, 2018, https://www.iso-ne.com/static-assets/documents/markets/hstdata/rpts/net_eng_peak_load_sorc/energy_peak_source.xls.

ISO New England. n.d. “New England’s Electricity Use.” Accessed March 16, 2018, https://www.iso-ne.com/about/key-stats/electricity-use.

ISO New England. n.d. "Resource Mix." Accessed March 16, 2018, https://www.iso-ne.com/about/key-stats/resource-mix.

Lazard. 2017. “Lazard’s Levelized Cost of Energy Analysis—Version 11.0.” Accessed April 11, 2018, https://www.lazard.com/media/450337/lazard-levelized-cost-of-energy-version-110.pdf.

Lazard. 2017a. “Levelized Cost of Energy 2017.” Last modified November 2, accessed April 11, 2018, https://www.lazard.com/perspective/levelized-cost-of-energy-2017/.

McKenna, Phil. 2018. "New Jersey to Rejoin East Coast Carbon Market, Virginia may be Next." *InsideClimate News*, Jan 29, 2018. https://insideclimatenews.org/news/26012018/cap-and-trade-carbon-emissions-regional-greenhouse-gas-initiative-rggi-new-jersey-virginia-climate-change.

National Energy Board, Government of Canada. 2018a. "Provincial and Territorial Energy Profiles – British Columbia." Last modified January 4, accessed March 25, 2018, https://www.neb-one.gc.ca/nrg/ntgrtd/mrkt/nrgsstmprfls/bc-eng.html.

National Energy Board, Government of Canada. 2018b. "Provincial and Territorial Energy Profiles - New Brunswick." Last modified January 4, accessed March 25, 2018, https://www.neb-one.gc.ca/nrg/ntgrtd/mrkt/nrgsstmprfls/nb-eng.html.

National Energy Board, Government of Canada. 2018c. "Provincial and Territorial Energy Profiles – Quebec." Last modified January 4, accessed March 25, 2018, https://www.neb-one.gc.ca/nrg/ntgrtd/mrkt/nrgsstmprfls/qc-eng.html.

National Renewable Energy Laboratory. n.d. “Biomass Energy Basics.” Accessed April 19, 2018, https://www.nrel.gov/workingwithus/re-biomass.html.

National Renewable Energy Laboratory. n.d. “Renewable Portfolio Standards.” Accessed April 19, 2018, https://www.nrel.gov/technical-assistance/basics-portfolio-standards.html.

Province of British Columbia. 2017. “1990-2015 BC Provincial GHG Inventory.” [Excel Document] https://www2.gov.bc.ca/assets/gov/environment/climate-change/data/provincial-inventory/2015/2015_provincial_inventory.xlsx

Province of British Columbia. “British Columbia’s Revenue-Neutral Carbon Tax.” Accessed March 12, 2018, https://www2.gov.bc.ca/gov/content/environment/climate-change/planning-and-action/carbon-tax.

Ramseur, Jonathan L. 2017. "The Regional Greenhouse Gas Initiative: Lessons Learned and Issues for Congress." *Congressional Research Service: Report*: 1.

RGGI, Inc. n.d. "Program Design Archive." Accessed April 22, 2018, https://www.rggi.org/program-overview-and-design/design-archive.

RGGI, Inc. n.d. "Elements of RGGI." Accessed March 12, 2018, https://www.rggi.org/program-overview-and-design/elements.

RGGI, Inc. n.d. "Allowance Prices and Volumes." Accessed April 19, 2018, https://www.rggi.org/auctions/about-auctions.

RGGI, Inc. n.d. "About Auctions." Accessed April 19, 2018, https://www.rggi.org/auctions/about-auctions.

RGGI, Inc. 2016. "CO2 Emissions from Electricity Generation and Imports in the Regional Greenhouse Gas Initiative: 2014 Monitoring Report." August 12, accessed April 18, 2018, https://www.rggi.org/sites/default/files/Uploads/Electricity-Monitoring-Reports/2014_Elec_Monitoring_Report.pdf.

Tietenberg, Tom H. 2013. "Reflections—Carbon Pricing in Practice." *Review of Environmental Economics and Policy* 7 (2): 313-329. doi:10.1093/reep/ret008.

U.S. Energy Information Administration. 2018. "Electric Power Monthly with Data for December 2017." February 2018, accessed February 28, 2018, https://www.eia.gov/electricity/monthly/archive/february2018.pdf.

U.S. Energy Information Administration. 2017. "Electric Power Monthly with Data for December 2016." February 2017, accessed February 28, 2018, https://www.eia.gov/electricity/monthly/archive/february2017.pdf.

U.S. Energy Information Administration. 2016. "Electric Power Monthly with Data for December 2015." February 2016, accessed February 28, 2018, https://www.eia.gov/electricity/monthly/archive/february2016.pdf.

U.S. Energy Information Administration. 2015. "Electric Power Monthly with Data for December 2014." February 2015, accessed February 28, 2018, https://www.eia.gov/electricity/monthly/archive/february2015.pdf.

U.S. Energy Information Administration. 2014. "Electric Power Monthly with Data for December 2013." February 2014, accessed February 28, 2018, https://www.eia.gov/electricity/monthly/archive/february2014.pdf.

U.S. Energy Information Administration. 2013. "Electric Power Monthly with Data for December 2012." February 2013, accessed February 28, 2018, https://www.eia.gov/electricity/monthly/archive/february2013.pdf.

U.S. Energy Information Administration. 2012. "Electric Power Monthly: February 2012." February 2012, accessed February 28, 2018, https://www.eia.gov/electricity/monthly/archive/february2012.pdf.

U.S. Energy Information Administration. 2011. "Electric Power Monthly: March 2011." March 2011, accessed February 28, 2018, https://www.eia.gov/electricity/monthly/archive/march2011.pdf.

U.S. Energy Information Administration. 2010. "Electric Power Monthly: March 2010." March 2010, accessed February 28, 2018, https://www.eia.gov/electricity/monthly/archive/pdf/02261003.pdf.

U.S. Energy Information Administration. 2009. "Electric Power Monthly: March 2009." March 2009, accessed February 28, 2018, https://www.eia.gov/electricity/monthly/archive/pdf/02260903.pdf.

U.S. Energy Information Administration. 2008. "Electric Power Monthly: March 2008." March 2008, accessed February 28, 2018, https://www.eia.gov/electricity/monthly/archive/pdf/02260803.pdf.

U.S. Energy Information Administration. 2007. "Electric Power Monthly: March 2007." March 200-7, accessed February 28, 2018, https://www.eia.gov/electricity/monthly/archive/pdf/02260703.pdf.

U.S. Energy Information Administration. 2018a. "Energy-Related Carbon Dioxide Emissions by State, 2000–2015." Washington, DC: https://www.eia.gov/environment/emissions/state/analysis/pdf/stateanalysis.pdf

U.S. Energy Information Administration. n.d. "New York - Rankings: Total Energy Consumed Per Capita, 2015 (Million BTU)." Accessed March 23, 2018, https://www.eia.gov/state/rankings/?sid=NY#series/12.

U.S. Environmental Protection Agency. 2015. "Chapter 5. Renewable Portfolio Standards." *EPA Energy and Environment Guide to Action (2015 Edition)*. Washington, DC: Environmental Protection Agency. Accessed April 17, 2018, https://www.epa.gov/sites/production/files/2017-06/documents/guide_action_chapter5.pdf.

XE.com. 2018. "XE Currency Converter: CAD to USD." Accessed April 29, 2018 (17:15 UTC), https://xe.com/currencyconverter/convert/?Amount=30&From=CAD&To=USD.

XE.com. 2018a. "XE Currency Converter: EUR to USD." Accessed April 29, 2018 (17:06 UTC), https://xe.com/currencyconverter/convert/?Amount=13.22&From=EUR&To=USD.

Appendices

Appendix A

RGGI Combined Electricity Sales Data (2005-2017)

	CT	DE	ME	MD	MA	NH	NY	RI	VT	Total	Generation	Difference
2005	33095	12137	12363	68365	57228	11245	150148	8049	5883	**358513**	330200	-28313
2006	31677	11555	12285	63173	55850	11094	142238	7799	5795	**341466**	320341	-21125
2007	34129	11869	11860	65391	57139	11236	148178	8013	5864	**353679**	327064	-26615
2008	30957	11749	11674	63326	55884	10977	144053	7819	5741	**342180**	312583	-29597
2009	29716	11258	11283	62589	54359	10698	140043	7618	5497	**333061**	294624	-38437
2010	30392	11606	11532	65335	57123	10890	144624	7799	5595	**344896**	307338	-37558
2011	29859	11483	11415	63600	55570	10869	144047	7732	5550	**340125**	300036	-40089
2012	29492	11519	11561	61814	55313	10870	143163	7708	5511	**336951**	293073	-43878
2013	29825	11348	11855	61899	55265	11043	147895	7781	5589	**342500**	284592	-57908
2014	29354	11338	12003	61684	54469	10944	147372	7643	5570	**340377**	284499	-55878
2015	29476	11498	11888	61782	54621	10999	148914	7665	5521	**342364**	284646	-57718
2016	28931	11258	11449	61354	53476	10905	147803	7524	5516	**338216**	279946	-58270
2017	27994	10920	11407	59174	60058	10750	143755	7385	5392	**336835**	262782	-74053
Change in Consumption	**-15.41%**	**-10.03%**	**-7.73%**	**-13.44%**	**4.95%**	**-4.40%**	**-4.26%**	**-8.25%**	**-8.35%**	**-6.05%**	**-20.42%**	**161.55%**
Change in Generation	-0.25%	-14.79%	-35.33%	-35.89%	-34.29%	-27.75%	-13.05%	-13.25%	-63.55%	-20.42%		

Source: U.S. Energy Information Administration 2007; 2008; 2009; 2010; 2011; 2012; 2013; 2014; 2015; 2016; 2017; 2018

Appendix B

RGGI Combined Electric Power Sector Generation Data (2005-2017)

Year	Coal	Petroleum	Natural Gas	Nuclear	Hydro	Renewables	Other	Total
2005	73795	40474	82839	91711	34153	7228	3270	330200
2006	73726	11160	94634	92977	36595	7966	3283	320341
2007	75599	14132	100350	93780	31323	8677	3203	327064
2008	69399	6995	94581	93435	35660	9277	3236	312583
2009	53581	4453	92156	94266	36658	10474	3036	294624
2010	53235	3148	108925	94225	33501	11312	2992	307338
2011	38177	1833	116746	91375	37666	11254	2985	300036
2012	25725	943	128650	90470	32398	11890	2997	293073
2013	27444	2080	109549	96203	33046	13455	2815	284592
2014	27549	4635	106544	94221	33807	14992	2751	284499
2015	20322	4062	117568	91136	33172	15730	2656	284646
2016	18202	1454	118985	89082	33088	16460	2675	279946
2017	11030	1,313	104375	88811	36627	18016	2610	262782
	-85.05%	**-96.76%**	**26.00%**	**-3.16%**	**7.24%**	**149.25%**	**-20.18%**	**-20.42%**

Source: U.S. Energy Information Administration 2007; 2008; 2009; 2010; 2011; 2012; 2013; 2014; 2015; 2016; 2017; 2018

Appendix C

RGGI Combined Renewable Electric Power Sector Generation Data (2010-2017)

	2010	2011	2012	2013	2014	2015	2016	2017	% Change
Wind	3212	3960	4594	5723	6310	6643	7084	7726	140.54%
Biomass	8101	7272	7168	7445	8125	8303	8287	8442	4.21%
Solar PV	1	23	130	297	559	787	1091	1851	185000.00%
Total	**11314**	**11255**	**11892**	**13465**	**14994**	**15733**	**16462**	**18019**	

Percentage of Renewables									
Wind	28.39%	35.18%	38.63%	42.50%	42.08%	42.22%	43.03%	42.88%	
Biomass	71.60%	64.61%	60.28%	55.29%	54.19%	52.77%	50.34%	46.85%	
Solar PV	0.01%	0.20%	1.09%	2.21%	3.73%	5.00%	6.63%	10.27%	

¬ Source: U.S. Energy Information Administration 2007; 2008; 2009; 2010; 2011; 2012; 2013; 2014; 2015; 2016; 2017; 2018

Appendix D

Energy-Related CO2 Emissions Data (2005-2015)

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Percentage
Connecticut	44.1	41	40.3	37.7	35.9	36.2	34.9	34.1	34.9	35.1	36.5	**-17.23%**
Delaware	17.4	16.2	17.1	16.2	12	11.8	12.9	13.9	13.6	13.3	13.4	**-22.99%**
Maine	23.1	21.3	21	19.1	18.4	18.1	17.6	15.9	16.6	16.6	16.8	**-27.27%**
Maryland	83.5	77.2	77.5	73.8	70.5	69.1	64.4	59.9	59.2	61.3	59.5	**-28.74%**
Massachusetts	84.5	76.5	79.9	76.7	70.3	71.8	68	61.7	65.6	63.7	65.6	**-22.37%**
New Hampshire	21.3	19.4	19.2	18.7	17.1	16.6	16.2	14.6	14.3	14.9	15.1	**-29.11%**
New York	211.6	193.2	199.6	190	173.9	174.5	164.9	161.5	162.7	170.1	168.3	**-20.46%**
Rhode Island	11.2	10.5	11.1	10.7	11.3	11	11	10.5	10.2	10.6	10.9	**-2.68%**
Vermont	6.8	6.7	6.5	5.9	6.2	5.9	5.8	5.5	5.8	5.9	6.1	**-10.29%**
RGGI Total	503.5	462	472.2	448.8	415.6	415	395.7	377.6	382.9	391.5	392.2	**-22.11%**
National Total	5,948.90	5,879.70	5,975.30	5,780.60	5,364.20	5,557.40	5,423.20	5,208.00	5,341.90	5,391.60	5,249.30	**-11.76%**
Rest of Nation	5,445.40	5,417.70	5,503.10	5,331.80	4,948.60	5,142.40	5,027.50	4,830.40	4,959.00	5,000.10	4,857.10	**-10.80%**

Source: U.S. Energy Information Administration 2007; 2008; 2009; 2010; 2011; 2012; 2013; 2014; 2015; 2016; 2017; 2018

Appendix E

CO_2 Emissions from RGGI Region

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
RGGI-Affected Units	159,287,880	139,924,128	145,789,425	129,374,761	105,958,243	116,053,938	101,456,734	92,212,271	86,517,389	88,360,436
Non-RGGI Fossil Fuel-Fired Units	10,309,984	10,134,399	8,443,421	4,662,824	4,263,698	5,355,842	5,401,761	6,459,299	8,193,802	8,974,623
Non-Fossil Fuel-Fired Units	6,586,892	10,470,954	10,446,982	11,793,728	10,584,284	10,800,970	11,333,807	11,005,795	11,163,981	10,284,609
Net Imports - From Ontario to NY	460,286	769,120	604,715	1,154,884	712,496	554,950	336,556	602,081	795,236	603,144
Net Imports - From Quebec to NY & NE	30,081	39,607	39,262	41,725	67,723	37,339	47,363	66,408	54,159	48,617
Net Imports - From New Brunswick to NE	714,298	547,053	455,316	736,564	968,535	406,202	410,324	297,690	1,186,296	1,127,493
Net Imports - From non-RGGI PJM to NY	4,460,362	5,484,024	5,801,823	5,999,390	4,381,845	6,656,944	5,952,203	4,287,069	4,822,624	4,534,250
Net Imports - From non-RGGI PJM to RGGI PJM	20,408,108	19,059,750	17,766,431	17,172,335	18,682,706	20,361,849	19,504,235	18,627,737	19,867,713	17,971,031

Source: RGGI, Inc. 2016., p.15