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A Study of Renewable Portfolio Standards and Renewable Energy Certificate Prices in Five Northeastern States

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Abstract

A number of US states have passed renewable portfolio standard, a mandate that ensures a certain amount of energy to be generated by renewable sources, to offset carbon emission or create local jobs. While states' renewable portfolio standards have similar features, their designs vary substantially. In this paper, I investigate the design features and renewable energy certificate prices in five northeastern states that are trading in two trading systems to see how renewable portfolio standards are working in those states. The regression on bidding and asking price differences reveals considerable differences among states in Class I renewable energy certificate prices and differences between bid and asking price. This leads us to question the effectiveness of these portfolio standards.

Introduction

Fossil fuel consist 87% of current global energy consumption in 2009 (Delimatsis, 2009). One well-known consequence of the burning of fossil fuel is carbon emission, which is considered a main cause of environmental issues such as global climate change and sea level rising. A large fraction of carbon emissions are due to the burning of fossil fuels, especially, to generate electricity. Total energy-related carbon dioxide emission was estimated to be 5999 million metric tons in 2005 and will be 5691 million metric tons in 2040 (Annual Energy

Outlooik, 2013). In order to deal with the more and more challenging issues that results from the use of fossil fuels like energy security, climate change and high fossil fuel prices, many states in the US are setting up Renewable Portfolio Standards(RPS) to limit fossil fuel consumption. RPS programs are quantity-based policies which typically require that a minimum fraction of electricity demand be met by state eligible renewable energy sources. As of May 2013, thirty eight states and the District of Columbia had enacted RPS programs, along with other renewable energy policies. Since 2007, the U.S. House of Representatives has twice passed bills that would impose a nationwide RPS (Schmalensee, 2011). The Federal RPS, however, has not yet been signed into law (Wiser et al, 2007). The recently enacted RPS programs by the states, if met, would collectively require US electricity generators to use about 20% renewable sources by 2025, which would be more than double of that in 2009 (Johnson and Moyer, 2012).

To effectively promote and facilitate the use of renewable energy, state governments have taken important steps towards a future of renewable energy through the enactment of innovative instruments for the development of clean energy technologies. The RPS requires that the electricity purchasing process include the purchase of corresponding government certificates to support the generation of electricity from renewable energy sources. This is called Renewable Energy Certificate (REC) policy. In New Jersey, for example, the department of energy requires electricity distributors to have 20.38% of their sales having RECs in energy year 2027-2028. RECs represent the environmental attributes of one megawatt-hour (MWh) of generation from eligible renewable generators. The electric serving entities are typically required, under the REC policy, to obtain RECs to a certain proportion of their retail sales. Eligible renewable energy sources typically include wind, biomass, solar, hydropower or others. The renewable energy are generally categorized into different tiers or classes based on the way it was generated. The specific differences of each state's RPS and REC are presented in later chapters.

RPS and REC are an inseparable system that forces electricity generators to procure a certain minimum quantity amount of renewable energy. Delimatsis (2009) provides a good description of the mechanics of how RPS and REC work together. The power generators usually gather electricity to a power pool. Electricity distributors then purchase electricity from this pool by bid. Traditionally electrons that make up commodity electricity are physically the same and cannot be identified as coming from traditional energy sources or renewable sources (Delimatsis, 2009). RPS programs therefore solve the problem by placing direct obligation on power plants and issuing RECs to them.

Under a RPS, electricity produced by renewable generators generates two sources of benefit for the generators: firstly, the energy that is produced or used on-site; secondly, the positive environmental attributes associated with the renewable energy production. REC reflects the second part. RECs are created by the tracking system and then attributes to the generators. The generators can then sell the RECs to the electricity generators which would bring them further compensations for generating renewable energy. Hence RECs are in fact tradable financial assets reflecting the value created by the unbundling the environmental attributes of one MWh of electricity from a renewable energy source (Gillenwater 2008). RPS and REC are inseparable since the possession of a specific number of RECs confirms that a supplier or distribution company has complied with the minimum share obligation.

Although the federal government is proposing a national-wide RPS program, currently specific policies are based on states. States have created REC tracking systems to verify compliance with RPS targets. The system also tracks the attributes of RECs, such as the type of renewable energy facility, for example, wind or biomass, project location and the generation date (Heeter and Bird, 2011). Utilities will use the tracking system to manage their REC portfolios, transfer RECs to others, and of course, demonstrate their compliance with the RPS by transferring RECs into retirement accounts. In United States, there are nine different tracking systems which are shown in figure 1. The primary regional markets exist in New England and the Mid-Atlantic states (Heeter and Bird, 2011) Most New England states are covered in New England Power Pool-Generation Information System (NEPOOL-GIS), whereas states such as New Jersey, Ohio, Pennsylvania are covered by PJM-Generation Attribute Tracking System (PJM-GATS). The REC tracking system not only ensures that RECs are properly "retired" but also creates a system of REC trading. Within the PJM-Interconnection, for example, most states allow for RECs to come from within or to be sent out to another state in the PJM system. As a result of this restriction, states that are not in the same trading system are forbidden to trade with states in the system (Heeter and Bird, 2011). This potentially led to significant difference in the formation of REC prices in the states this study is concerning even though they might be adjacent to each other.

This research is primarily interested in how the RPS programs in five northeastern states are performing. In the following sections, I will first review some academic studies of state and national Renewable Portfolio Standard policies. Then I will perform quantitative analyses and qualitative interpretations of REC prices data.

Tracking System	Primary Region(s)	Launch Date
Texas Renewable Energy Credit Program	Texas	January 2002
NEPOOL-GIS	New England	July 2002
PJM-GATS	Delaware, Indiana, Illinois, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, and Washington, D.C.	Sept 2005
WREGIS	Alberta, Arizona, British Columbia, California, Colorado, Idaho, Montana, Nebraska, Nevada, New Mexico, Oregon, Texas, Utah, Washington, and Wyoming	June 2007
M-RETS	Illinois, Iowa, Manitoba, Minnesota, Montana, North Dakota, South Dakota, and Wisconsin	July 2007
NVTREC	Nevada	2007/2008
NARR	States and provinces not covered by the regional markets	February 2009
MI-RECS	Michigan	October 2009
NC-RETS	North Carolina	2010

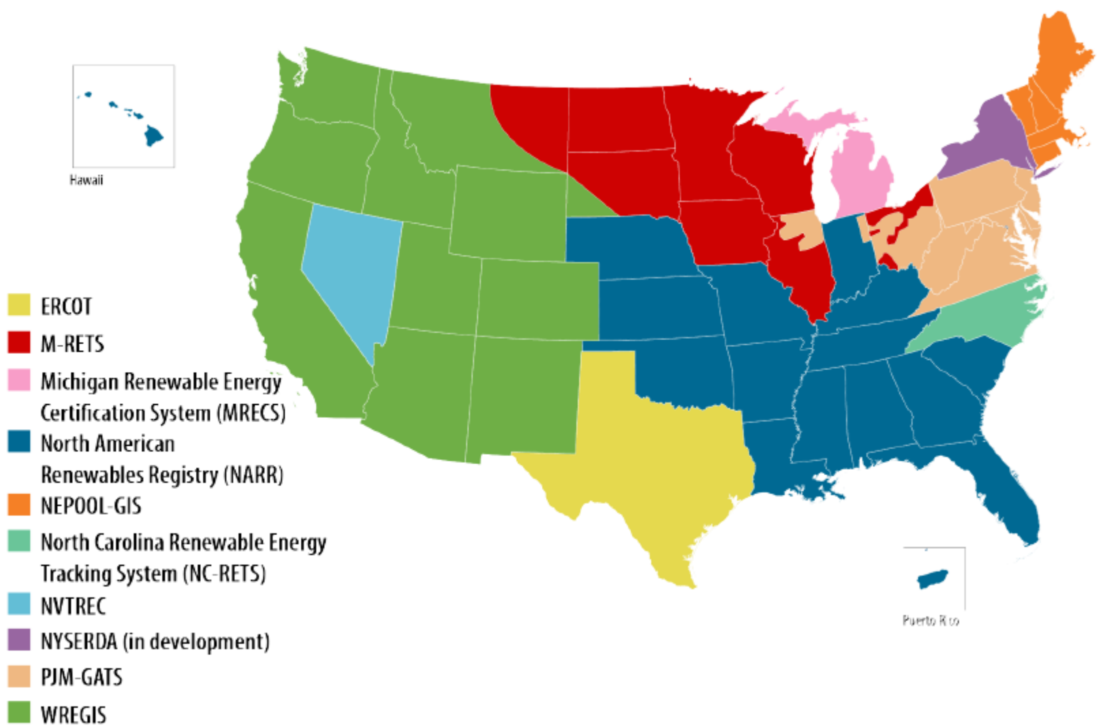


Figure 1. REC Tracking Systems Overview. (Heeter and Bird, 2011)

Literature Review

There are numerous studies and market reports analyzing RPS programs and the REC mechanisms. Many works have been done on the description and basic analysis of RPS in one or few US states. By its definition, RPS is a policy approach that mandates an increase in the share of renewable energy supplied to the electricity market. The reason for this policy might vary depending on the objectives of each state. Whether the total volume of the mandate and the specific regulations can pass cost benefit analysis is often dubious (Carley, 2009). Most of the current literature on RPS seems to be somewhat descriptive. Some focus on the cost benefit analysis of RPS program in specific state. The supporters of RPS programs argue that RPS has a clear benefit which is that it could work as an effective obligation that guarantees renewable energy growth (Schmalensee, 2011).Some others focus on the REC trading from the perspective of electricity generators. In this section, I will first present some studies on RPS and then discuss a few papers related to REC.

RPS is not the only approach to increase the share of renewable energy in the world, but many argue that it is currently the strongest policy that the US has to address climate change. Some studies questioned its effectiveness in terms of actually increasing renewable energy share. Carley (2009) states that RPSs are regarded as one of the most prevalent and innovative policy instruments that promote carbon mitigation and renewable energy development. Carley evaluates the effectiveness of state energy programs with an empirical investigation of the linkage between state RPS policy implementation and the percentage of renewable energy electricity generation across states. His results indicate that states that have RPS do not have statistically higher renewable energy share deployment than states that do not, but they do have statistically higher total volume of renewable energy deployment, holding all other factors equal (Carley, 2009). In other words, RPSs do effectively increase the states' renewable energy total deployment. However they do not collectively increase the percentage share of renewable energy in total energy consumption. This result is strange because it is rather inconsistent with the RPS's overall goal. Carley thinks that these findings reveal that the outcome of RPS is far from successful and the reason might attribute to the states' poorly constructed RPS policy structures. Political institutions, natural resource endowments, deregulation, and gross state product per capita, electricity use per person, electricity price, and the presence of regional RPS policies are all factors found to be significantly related to renewable energy deployment. Hence, the legislators have to be cautious about the set-up of RPS policies since RPSs do not guarantee a states' renewable energy generation objective.

Renewable energy policy has far-reaching implications for national and international economic, environmental, and political sustainability, but thus far within the United States it has been almost entirely administrated by the state governments. In another paper, Carley and Miller (2012) examine the factors motivating state-level policymakers to adopt different forms of RPS, highlighting the distinction between degrees of policy stringency, ranging from entirely voluntary participation to rigorous and strictly enforced targets. In the process Carley and Miller utilize a more precise metric to assess the stringency of RPS programs. They find that policies of different stringencies are motivated by systematically different underlying factors. Among the factors, state-level citizen political ideology is a significant predictor of RPS policy adoption, particularly for "voluntary" and "weak" policy designs. "Strong" policy designs, on the other hand, are best predicted by ideology at the government level, i.e., the degree of institutional liberalism which is a socio-economic variable used in Carley and Miller's paper. Informed by the findings of Carley and Miller, we might believe that the rationale behind RPS policies is beyond mere energy policy. The efficiency of RPS programs, therefore, must be also looked at under other dimensions such as institutional structures and political environment such as ideology.

Another important type of analysis focuses more on micro-level economic assessment of RPSs. These analyses usually perform analysis in one state and then generalize the result to a larger level. Johnson and Moyer's (2012) paper is a classic example of this type of research. They did a thorough analysis of RPS program in Illinois. They hope to use Illinois RPS as an example to examine the effectiveness of emission mandate in the US more generally. They argue that the fundamental factor that determines whether the renewable energy policies are viable or not are whether the state has efficient renewable sources. In Illinois, where eligible wind or solar sources can be found both in-state and out-of-state, the abundance of renewable energy sources is not a problem. However, worries arise that combining multiple objectives under a single legislation would be problematic (Johnson and Moyer, 2012). Johnson and Moyer's analysis also shows some potential conflicts between RPS legislation and the legislators' objectives. The desire for lower prices can be in conflict with the goal of local jobs creation. The development and subsidy for wind energy might transfer rate-payers' investment to more wind-endowed Iowa. Furthermore, because solar electricity is generally significantly more costly than wind at present, distributing more subsidies into solar programs does not produce the maximal reduction in carbon emissions. Hence if RPS success requires substantial cost reduction in renewables, it is worth evaluating whether the RPS can help bring about those decreases. The Illinois RPS, like that of many other states, appears to combine objectives inherently in conflict: preferences for local jobs, for specific technologies, for environmental benefits, and for low costs. Revisiting the legislation may be needed to make legislative success likely and to ensure that failure modes do not compromise goals (Johnson and Moyer, 2012).

More questions on the outcome of RPS policies are discussed in a paper done by Yin and Powers (2009). Yin and Powers think that existing research on RPS effectiveness has either employed a cross sectional approach or has ignored heterogeneity among RPS policies in different states (Yin and Powers, 2009). When factors like RPS design features are accounted, Yin and Powers found significant positive effect of RPS on in-state renewable energy development. But they argue that looking at just RPS do not give us the whole story. Some seemingly aggressive RPS policies in fact provide only weak incentives, while some seemingly moderate RPS policies are in fact relatively ambitious. Furthermore, they found that when a state allows “free trade” of RECs, the effectiveness of RPS is reduced. Therefore the effectiveness of RPS can be unpredictable, even though they might seem predictable. Together with the Johnson and Moyer study, the papers reveal that the outcome of RPS is fairly unpredictable and the objectives can be unsatisfactory given the high cost of renewable energy at present.

Delimatsis (2009) acknowledges that the need for a global collaboration of mitigating carbon emission is imminent. The EU, for instance, pledges an ambitious 30% reduction of its GHG emissions by 2020 when compared to the 1990 emissions levels and the energy plan employed by the Obama administration now matches or will even exceed the level of the EU plan (Delimatsis, 2009) He points out that energy has come to the forefront of the public debate in the past decades for two major reasons: first, the lack of a secure, continuous source of energy supply for the industrialized countries and second, the environmental degradation and global warming resulted from the use of conventional energy. He states that there are two sources of income for a renewable energy source generator through the REC scheme: firstly, vending the physical electricity produced on the grid at market price, and secondly is the prices of the REC sales. Although it seems prominent that REC will surely stimulate a growth of renewable energy generation, Delimatsis' analysis indicates that REC trading can raise several issues of relevance to the General Agreement on Trade in Services (GATS) and the regulation of trade in financial services.

Schmalensee (2011) uses the same dataset from Spectron Group that I am using in my analysis. It is end-of-month bid-ask data from May 2006 through Augst 2010. Schmalensee is concerned with the efficiency of US's RPS program. Schmalensee acknowledges that feed-in-tariff (FIT) policy is more popular outside of the US. FITs are price-based policy which requires that energy generated from renewable energy sources be bought at a fixed premium price. From a global perspective, FIT is more popular. As of year 2010, fifty nations adopted FIT and only 10 are using RPS (Schmalensee, 2011). Schmalensee argues that the range of REC prices is too wide which might indicate ex-post inefficiency in meeting states goals for renewable generation. He also notes that although the RPS program could potentially be more efficient than the FIT program, which is more popular globally, the US RPS program is made less efficient because the REC markets are generally fragmented and thin. The conclusion that FIT may be superior to RPS is based on the experience in some EU countries. In regimes that adopted FIT, such as Spain and Germany, the result outperformed the RPS program in the United Kingdom. However this result is not guaranteed since the complex policy characteristics are not examined carefully (Schmalensee, 2011).

Finally, since I am going to argue that a wide spread between bid and asking price in a market indicate thin-trading, I did some research on the literature about thin markets. Rostek and Weretka (2008) present an insightful analysis of thin markets. Traditionally, the bid and ask spread is often studied in the finance market. A thin market is a market with few buying or selling offers. The concept of market thinness, while general, is typically used in the context of financial markets. When the number of buying or selling offers is small, investors' trading positions are large relative to market size. Trading then requires price concessions and thus exerts an impact on prices. A thin market is characterized by low trading volume, high volatility and high bid–ask spreads (Rosetek and Weretka, 2008). REC markets might experience similar sort of thin market because of few players are bidding in the market.

Data Analysis Introduction

The current literature on RPS policies and REC markets has emphasized a worry that RPS is not functioning efficiently. Some researchers argue that other possible approaches by doing comparison between REC and FIT programs might be superior and some tried to address cost efficiency analysis in a particular state. In this paper, I try to assess the healthiness of REC market in the five states by first examine their REC's price trend and then doing an analysis on the bid and ask spread in the five REC markets. There does not seem to be enough literature that addresses this aspect of the REC markets. As of my data, I purchased spot REC price records from Spectron Group, a leading broker based in the UK. The dataset contains spot bid and offer prices for all existing REC markets in the US from 2006 to 2012.

Because each state has its own interest, RPS programs are very different across states. In this paper, I look at REC markets in five Northeastern states: New Jersey, Maryland, Pennsylvania, Connecticut and Massachusetts. These five states are geographically close to each other and all have similar eco-geographic characteristics. However they are separated into different REC trading systems (see figure1). In the following section, I will first present a general outline of RPS programs in the five states. Most of the information on the RPS policy is acquired from the website of US Department of Energy's database of state incentives for renewables and efficiency (DSIRE).

In the data analysis part, I first generated graphs of REC prices for the five states. I then performed a regression analysis of the bid and ask price difference of REC price in each state by creating a variable measuring the difference between bid and offer price which allows me to test the bid-ask spread in the five states.

Introduction to RPSs in the 5 States

New Jersey

New Jersey's RPS program is one of the most aggressive in the United States. It requires each supplier/provider serving retail customers in the state to procure 22.5% of the electricity it sells in New Jersey from qualifying renewables by 2021.In addition; the standard also contains a separate solar specific provision which requires suppliers and providers to procure at least 4.1% of sales from qualifying solar electric generation facilities by Energy Year [1]2028. The suppliers/providers may meet these requirements by submitting "Class I" renewable-energy certificates (class I RECs), "Class II" RECS, and Solar RECs (SRECs).

Generally, electricity providers can submit RECs generated by all kinds of sources. But since some sources bear different costs, states usually categorize RECs into different classes or tiers. The RPS in New Jersey categorizes renewable energy from different types of sources as different "classes." The way in which New Jersey defines the classes is very representative. I will refer to Class I RECs as REC1, Class II RECs as REC2 and Solar RECs as SREC. "Class I"

[1] Energy Year typically runs from June to May. For example, Energy Year 2011 runs from June 2010 to May 2011.

renewable energy is defined as electricity derived from solar energy, wind energy, wave or tidal action, geothermal energy, landfill gas, anaerobic digestion, fuel cells using renewable fuels, and -- with written permission of the New Jersey Department of Environmental Protection (DEP) -- certain other forms of sustainable biomass according to DSIRE. In a newversion of the RPS that was enacted in July 2012, New Jersey Class I RECs now also includes hydroelectric facilities of 3 MW or less that falls into the following categories: placed in service after July 23, 2012 (the effective date of the new amendment to the RPS); located in the state and connected to the distribution system; and, certified as low-impact by a nationally recognized organizations based on a system that includes a variety of minimum criteria.

In addition to the primary RECs (Class I), "Class II" renewable energy in New Jersey, as in a number of other states across the US, is defined and accepted as a secondary REC source in order to promote the use of some specific types of renewable energy (Heeter and Bird, 2011). In New Jersey, Class II RECs are defined as electricity generated by hydropower facilities larger than 3 megawatts (MW) and less than 30 MW, and resource-recovery facilities (i.e., municipal solid waste or MSW) located in New Jersey approved by the department of environmental protection. Electricity generated by a resource-recovery facility outside New Jersey qualifies as "Class II" renewable energy if the facility is located in a state with retail electric competition and the facility is approved by the department of environmental protection. Finally solar energy, while it remains an eligible Class I technology, occupies a special place as the only resource eligible for the solar electric component of the standard. Offshore wind, defined as a wind turbine located in the Atlantic Ocean and connected to the New Jersey electric transmission system, likewise also occupies a special place within the RPS. Unlike other typical Class II REC markets, New Jersey created offshore wind RECs (ORECs) program in 2010 that requires a specific percentage of electricity to come from offshore wind electricity generators in order to facilitate the development of offshore wind electricity (Heeter and Bird, 2011).

Another general feature of the RPS policy that is present in most states is that generators are subject to a fee if a certain amount of RECs are not submitted. In New Jersey, if a supplier/provider is not in compliance for an energy year, the supplier/provider must remit an alternative compliance payment (ACP) and/or a solar alternative compliance payment (SACP) for the amount of RECs and solar RECs that were required but not submitted. The Bureau of Public Utilities determines prices for ACPs and SACPs, and reviews the prices each year. Thus the price of an ACP and an SACP is expected to be higher than the estimated competitive market cost of (1) the cost of meeting the requirement by purchasing a REC or solar REC, or (2) the cost of meeting the requirement by generating the required renewable energy. Hence ACP is in fact, the cap of REC price.

Both values of the ACP and the SACP have been constantly reviewed but the amount generally remained unchanged since their first establishment. In 2004, ACP and SACP were set at 50$ per Megawatt-hour (one REC) and 300$ per Megawatt-hour (one SREC). The ACP value is still the same today. All payments are collected and used to promote renewable energy projects.

Pennsylvania

Pennsylvania's RPS is called Alternative Energy Portfolio Standard (AEPS). It was first created in 2004 and many features and definitions of it seem to be clearer than New Jersey. The latest version of it requires each electric distribution company and electric generation supplier to retail electric customers in Pennsylvania to supply 18% of its electricity using alternative-energy resources by 2020. Like New Jersey, whose legislature created and heavily relies on solar renewable energy certificates (SRECs) to facilitate compliance with solar targets, Pennsylvania's standard also provides for a solar set-aside, mandating a certain percentage of electricity generated by photovoltaics. Pennsylvania's AEPS also includes demand-side management, waste coal, coal-mine methane and coal gasification as eligible technologies.

Similar to the setting in New Jersey, Pennsylvania also has two levels of REC markets, which are referred to as “Tier I” and “Tier II.” By May 31st, 2021, utilities ought to generate 8% of their electricity by using Tier I sources and 10% using Tier II sources. Generally, the eligible renewable energy must be produced within Pennsylvania or other states under the PJM systems. Tier I sources include new and existing facilities which produce electricity using the following sources/technologies: photovoltaic energy, solar-thermal energy, wind, low-impact hydro, geothermal, biomass, biologically-derived methane gas, coal-mine methane and fuel cells. Tier II sources include waste coal, distributed generation systems, demand side management, large scale hydro, municipal solid waste, wood pulping and manufacturing byproducts, and integrated gasification combined cycle coal technology. As of offshore wind resources, Pennsylvania does not have a ORECs system like the one in New Jersey.

Pennsylvania also adopted the ACP mechanism. Any shortfalls in Tier I and Tier II will count for 45$ per megawatt-hour. Like the SACP in New Jersey, the shortfalls in SREC will be penalized at a significantly higher value. The penalty received through the ACP will be collected and used to solely in support of alternative-energy projects.

Maryland

Maryland’s RPS program seems to be less stable than the other states even though the target at present seems to be ambitious. First enacted in May 2004 and revised in 2007, 2008, 2010, Maryland's Renewable Energy Portfolio Standard's aggressiveness is comparable to that of New Jersey. By the year of 2022, 18% of electricity is required to be provided by Tier I sources, 2% specifically by solar sources and 0% by Tier II (Maryland requires 2.5% of energy generated by Tier II for every year until 2019). The main revisions include: changing the duration of REC to three year instead of one year (RECs may be used in the year of generation and the following two years); restricting eligible sources to only PJM states while initially adjacent states to PJM were also considered eligible.

In addition to the standard RPS, the Maryland RPS included credit multipliers for wind, solar, and methane:

- A supplier received 120% credit toward meeting its Tier 1 obligations through RECs associated with wind energy through December 31, 2005. Beginning in 2006 and through 2008, a 110% credit was in effect.
- A supplier received 110% credit toward meeting its Tier 1 obligations through RECs associated with energy derived from methane through 2008.

Tier 1 resources include solar, wind, qualifying biomass (excluding sawdust), methane from the anaerobic decomposition of organic materials in a landfill or a waste water treatment plant, geothermal, ocean (including energy from waves, tides, currents and thermal differences), fuel cells powered by methane or biomass, and small hydroelectric plants (systems less than 30 megawatts in capacity and in operation as of January 1, 2004). As a result of S.B. 348 of 2008, poultry-litter incineration facilities connected to the Maryland distribution grid now qualify as a Tier 1 resource. Further, as a result of S.B. 690 enacted in May 2011 and effective October 1, 2011, waste-to-energy facilities and facilities that use refuse-derived fuel which are connected to the Maryland distribution grid also now qualify as Tier 1 resources. Prior to this, waste-to-energy facilities were only eligible as Tier 2 resources and facilities that use refuse-derived fuel were not specifically addressed. Tier 2 sources include hydroelectric power other than pump-storage generation, and waste-to-energy facilities through October 1, 2011 (see note above for further details).

Each unit of energy failed to meet the standard will be fined in a way similar to the ACP in New Jersey. The fee collected will be used to fund grant and loan programs for Tier 1 projects. The penalty schedule are: 4 cent/kilo-watthour for non-solar Tier I; 1.5cent for Tier 2 shortfalls; 45¢/kWh for solar shortfalls in 2008, 40¢/kWh in 2009 through 2014, 35¢/kWh in 2015 and 2016, 20¢/kWh in 2017 and 2018 and continuing to decline by 5¢ bi-annually until it reaches 5¢/kWh in 2023 and beyond; and 0.8¢/kWh for Tier 1 shortfalls for industrial process load in 2006-2008, declining incrementally to 0.2¢/kWh in 2017 and later; no fee for Tier 2 shortfalls for industrial process load.

Connecticut

Established in 1998 and subsequently revised several times, Connecticut's RPS requires each electric supplier and each electric distribution company wholesale supplier to obtain at least 23% of its retail load by using renewable energy by January 1, 2020.

The renewable sources are divided into three classes: Class I resources include energy derived from solar power, wind power, fuel cells (using renewable or non-renewable fuels), methane gas from landfills and anaerobic digestion, ocean thermal power, wave or tidal power, low-emission advanced renewable energy conversion technologies, certain newer run-of-the-river hydropower facilities not exceeding five megawatts in capacity, and sustainable biomass facilities. Emissions limits apply to electricity generated by sustainable biomass facilities.

Electricity produced by end-user distributed generation systems using Class I resources also qualifies. Class II resources include trash-to-energy facilities, certain biomass facilities not included in Class I, and certain older run-of-the-river hydropower facilities.

Class III resources include: customer-sited combined heat and power systems, with a minimum operating efficiency of 50%, installed at commercial or industrial facilities in Connecticut on or after January 1, 2006; (2) electricity savings from conservation and load management programs that started on or after January 1, 2006; and (3) systems that recover waste heat or pressure from commercial and industrial processes installed on or after April 1, 2007. The revenue from these credits must be divided between the customer and the state Conservation and Load Management Fund, depending on when the Class III systems are installed, whether the owner is residential or nonresidential, and whether the resources received state support.

The Connecticut electricity generators can show compliance to the program by submitting mainly Class I RECs. However, a certain fraction of Class I and be substituted by Class II RECs. According to the most recent schedule, providers should submit 20% Class I and either 3% Class I or II by January 1st 2020 and 4% Class III sources by 2010.

Electric providers that fail to comply with the RPS during an annual period must pay 5.5₵ per kWh; these payments will be allocated to the Connecticut Clean Energy Fund for the development of Class I renewables.

Massachusetts

In Massachusetts RPS are referred to as Alternative Energy Portfolio Standard (APS). The latest document targets 15% of the state's electric load with "alternative energy" by 2020, which is relatively less aggressive.

Eligible Class I resources include: photovoltaic; solar thermal-electric energy; wind energy; ocean thermal, wave or tidal energy; fuel cells utilizing renewable fuels; landfill gas; energy generated by certain new hydroelectric facilities, or certain incremental new energy from increased capacity or efficiency improvements at existing hydroelectric facilities; low-emission advanced biomass power conversion technologies using fuels such as wood, by-products or waste from agricultural crops, food or vegetative material, energy crops, algae, biogas, liquid biofuels; marine or hydrokinetic energy; and geothermal energy. Class II includes solar thermal-electric energy; wind energy and certain eligible hydroelectric facilities.

The Massachusetts ACP requires a 65.27$ per unit of REC1 shortfalls to be submitted. The solar shortfalls will be fined at a rate of 550$ per unit. Both are substantially higher than the New Jersey standards.

Delivery Requirements

As I have stated in the previous section, the five states that are presented in this papers can be divided in to two trading systems: Pennsylvania, Maryland and New Jersey are in the PJM-GATS; Connecticut and Massachusetts are in the NEPOOL-GIS. Figure 2 provides a good overview of the delivery requirement for these states. The delivery requirement shown in figure 2 indicates that these states are generally allowed to trade to a certain degree. Connecticut can certainly trade within New England but it seems that delivery from Pennsylvania, Maryland will go through more procedures. Massachusetts can only trade within New England. Maryland and Pennsylvania trade primarily within the PJM-GATS systems, no trading with the New England is allowed. New Jersey does not specifically restrict the states but requires energy to be delivered to the region which essentially creates a barrier for outsiders. Therefore, we might expect the prices in different trading system to be different. In the next section, I will present the prices in these five states.

	Delivered to region requirement
CT	Within New England ISO or from NY, PA, NJ, MD, or DE if the Connecticut Department of Public Utilities determines these states have an RPS comparable to Connecticut's.
MD	Located in adjacent state's ISO; must deliver to region. LSEs may also purchase unbundled RECs from states that are adjacent to PJM.
MA	Located in adjacent state's ISO; must deliver to region.
NJ	Generators anywhere outside region must deliver electricity to region.
PA	Within PJM or Midwest ISO (in areas served by MISO).

Figure 2. Geographic Eligibility and Delivery Requirements. (Heeter and Bird, 2011)

ISO: Independent System Operator.

REC Prices in the Five States

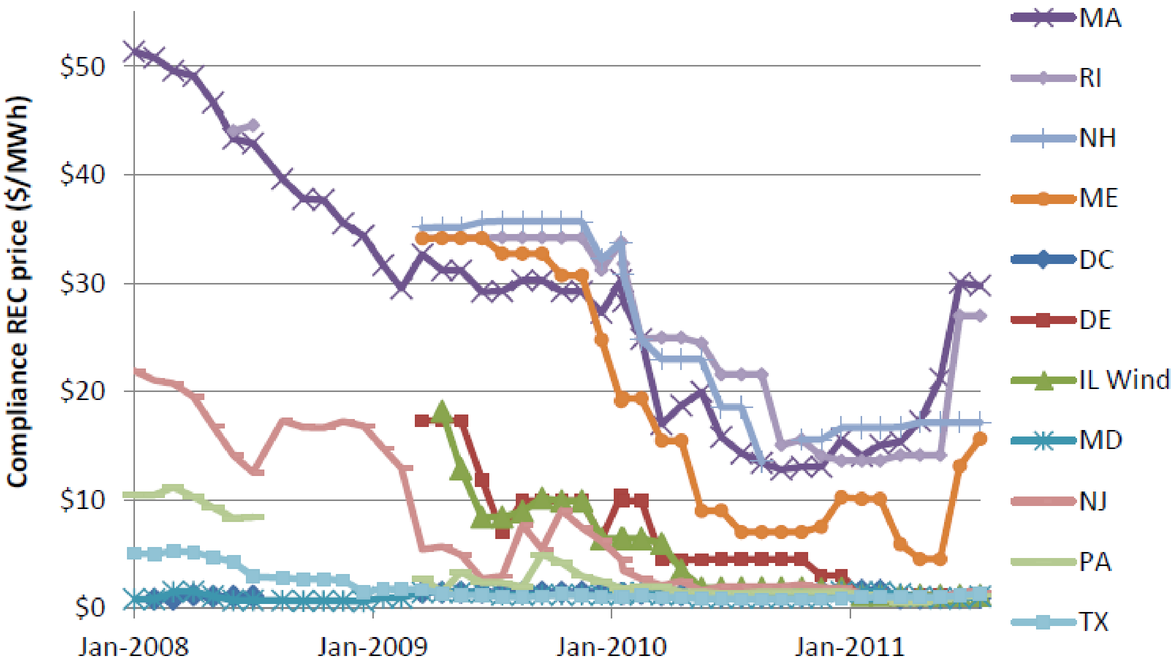


Figure 3. Overview of REC 1 [2]Prices (Heeter and Bird, 2011)

[2] Renewable energy that do not include solar and hydraulic power.

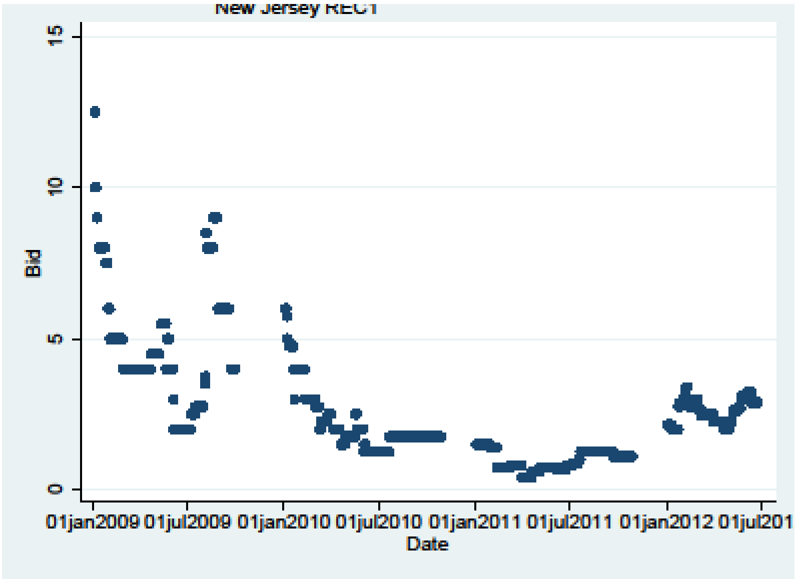


Figure 4. New Jersey Rec 1 Prices 2009-2012

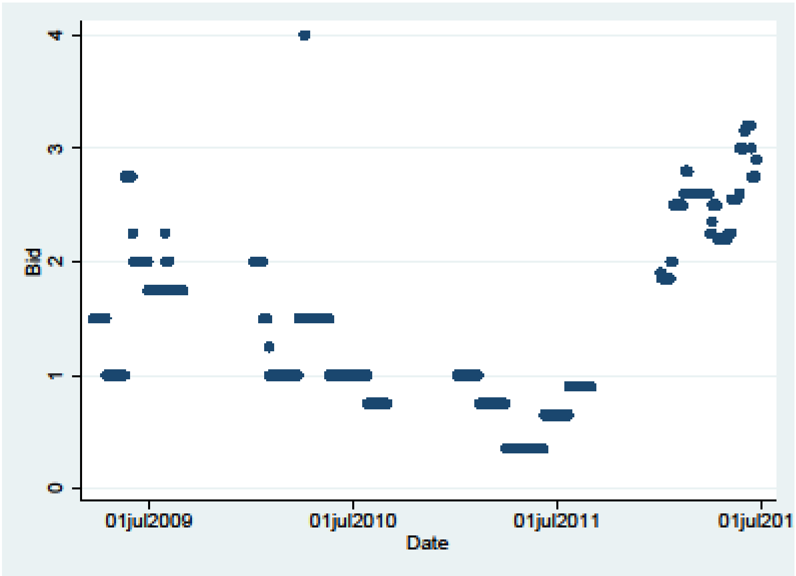


Figure 5. Pennsylvania REC 1 2009-2012

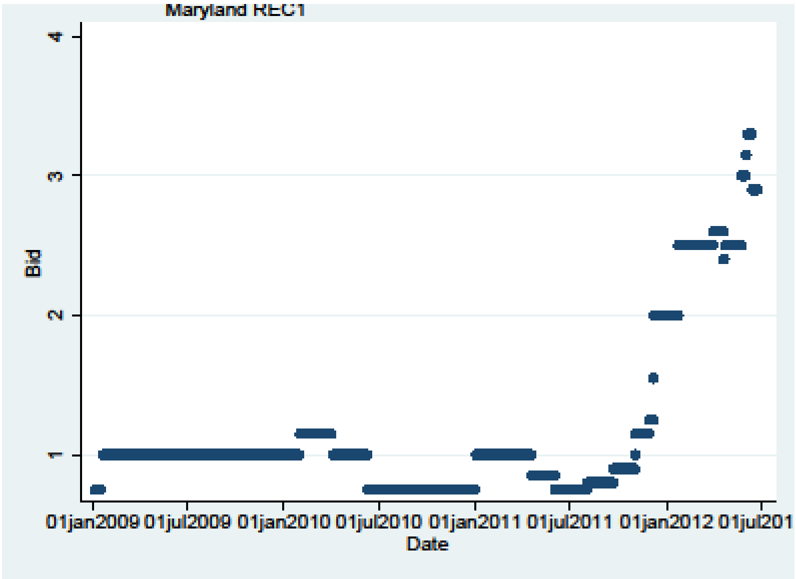


Figure 6. Maryland REC 1 2009-2012

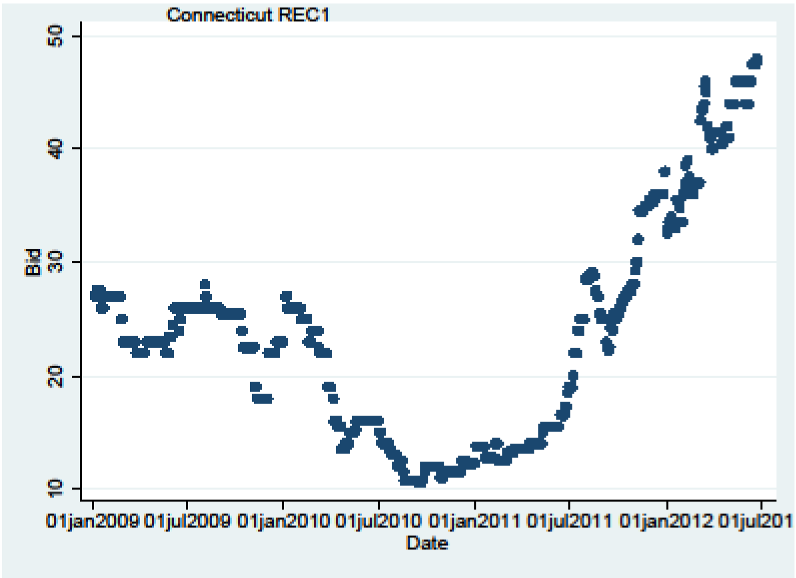


Figure 7. Connecticut REC 1 2009-2012

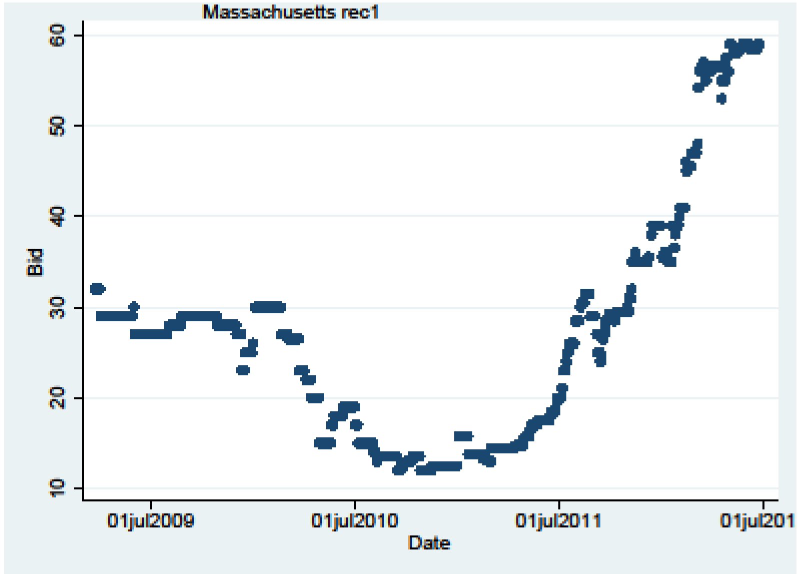


Figure 8. Massachusetts REC 1 2009-2012

Prices for different categories of RECs differ substantially. Appendix 1 shows the spot prices for REC1, REC2 and Solar REC in the five states in 2012. REC1 Prices in the two New England states are significantly higher than the other 3 states. REC2 prices are somewhat similar in Maryland, New Jersey and Connecticut, but Massachusetts REC2 prices are much higher whereas Pennsylvania REC2 prices are much lower. In terms of Solar REC, Massachusetts again has much higher prices than the other states. Hence in general all categories of REC prices are highest in Massachusetts, which might indicate that the RPS is better designed there.

Looking at prices over time could provide insightful on the REC markets in these states. Figure 3 indicates a large variation across the US. The general trend of REC price is first decreasing until about 2010 and then rises again afterwards. Massachusetts, Maryland, New Jersey and Pennsylvania are included in this graph. There is an obvious gap between the prices of the New England state with the other 3 states, although the general shape of the curves are similar. Figure 4 – 8 are REC1 prices in the five states from 2009 to 2012. The source of these data is Spectron Group which is the same dataset that Heeter and Bird used.

Judging by the REC 1 prices data from 2009-2012, states demonstrated substantial differences in REC prices. First of all, all the data points in Connecticut and Massachusetts, the two states trading in the NEPOOL-GIS, are above $10 for each REC. The latest Massachusetts REC prices have reached $60. The rates in all the PJM-GIS states are all below $5 at all-time except for New Jersey where the data were around 5$ to 10$ for a short period in 2009. The RPS schedule in the two states actually indicates that New Jersey is stricter than Massachusetts (by the year of 2020, New Jersey RPS requires 16.029% whereas Massachusetts requires 15%). Although New Jersey has one of the most aggressive RPS programs in the United States which means that the demand for REC should increase accordingly, its class I REC price tend to decrease from 2009 to 2012. Pennsylvania and Maryland's class 1 REC prices demonstrated totally different trend comparing to New Jersey. Their prices begin at a relatively low level in 2009 and eventually were raised to between 4$ and 5$ in 2012. Finally, Connecticut and Massachusetts first class REC markets are characterized by U shaped curves that are similar to Pennsylvania but at very different price level. They both start at a mediate level and then hit the low point around energy year 2011 and then quickly increased to a high level in 2012.

To summarize, there are a few characteristics shown by the spot prices that seem to be counter-intuitive, prima facie. Firstly, the general gap between PJM-GIS and NEPOOL-GIS are very large. The five states that are considered here do not have substantially differences in geo-graphical characters or RPS schedule. Therefore what might be the reason for the gap would be an interesting question to answer. Secondly, it seems strange that New Jersey, a state with a more ambitious RPS program, results in the lowest REC price of all the five states. Thirdly, it seems that among the two trading systems, prices eventually converged to the same. This could be explained by the trading among the trading system. However, this statement cannot explain why there was so much difference in the REC prices before they finally converged. And just why did they converged at the end of year 2011 is another question. Finally, Connecticut and Massachusetts' REC prices still vary for about 10$. Given the data that are currently available, we cannot know whether they would become the same in the future.

Source	**SS df**	**MS**	**Number of obs**	**=**	**163379.0000**
	F(7,163371)	=	3184.7500		
Model	20083.5591 7	2869.0799	Prob > F	=	0.0000
Residual	147177.8072	0.9009	R-squared	=	0.1201
	Adj R-squared	=	0.1200		
Total	167261.3662	1.0238	Root MSE	=	0.9492

abDiff	**Coef. Std.**	**Err.**	**t**
NJ	-.3228	.0051	-62.78
PA	-.0346	.0055	-6.26
CT	-.5117	.0051	-99.98
MA	-.5115	.0051	-99.39
ye09	.2729	.0056	48.67
ye10	.2219	.0047	46.85
ye11	.1631	.0048	33.84
Constant	.4427	.0053	83.31

Table 1. Regression of bidding and asking price difference as percentage. abDiff is the absolute value of the percentage of bidding and asking price difference.

NJ: New Jersey PA: Pennsylvania CT: Connecticut MA: Massachusetts

Ye09: year 2009 Ye10: year 2010 Ye11: year 2011

Source	SS df	MS	Number of obs	=	163379.0000
	F(7,163371)	=	3184.7500		
Model	20083.5591 7	2869.0799	Prob > F	=	0.0000
Residual	147177.8072	0.9009	R-squared	=	0.1201
	Adj R-squared	=	0.1200		
Total	167261.3662	1.0238	Root MSE	=	0.9492

abDiffamount	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
NJ	.2128	.0207	10.27	0.000	.1722	.2534
PA	.4748	.0223	21.31	0.000	.4311	.5184
CT	1.6226	.0206	78.67	0.000	1.5821	1.6630
MA	1.6741	.0207	80.71	0.000	1.6334	1.7147
ye09	1.5613	.0226	69.09	0.000	1.5170	1.6056
ye10	.4019	.0191	21.06	0.000	.3644	.4393
ye11	-.1389	.0194	-7.15	0.000	-.1769	-.1008
constant	.2650	.0214	12.37	0.000	.2230	.3069

Table 2. Regression of the amount of bidding and asking price differences. Variable are defined the same as Table 1. abDiffamount is absolute value of the amount of bidding and asking price difference.

The above regressions are aimed to test the bid and ask price in spread in the Class I REC markets of the five states. The data from New Jersey, Maryland and Connecticut runs from 2006 to 2012 whereas the data in the other two states only runs from 2009 to 2012. As a result of this lack of data, I ran the regressions based on the data after 2008. Both models also included the year variables from 2009 to 2011 and the five states. To avoid the problem of collinearity, I excluded Maryland and year 2012 from the regression. Therefore the constant in the model would represent Maryland and 2012 relative to the other variables. To get New Jersey's spread, for example, we need to add the coefficient of New Jersey to the coefficient of the constant.

In the first regression, dependent variable is the percentage change of the bid and ask price taken absolute value (|Bid- Offer/Bid|). The result shows that the spread in Connecticut and Massachusetts are very close to each other. The spread in Connecticut is 0.0690146 and the spread in Massachusetts is 0.0688205. Both of the two New England states' data are significantly higher than the other three states. Pennsylvania exhibits the largest gap, which is 0.4081. New Jersey's gap level seems to be in between of Pennsylvania and Massachusetts. It has a spread coefficient of 0.1199686. The year variables demonstrate a decreasing trend, indicating that the spread is decreasing for the five states on average. Because of the uniqueness of the data of New Jersey I performed an F-test comparing New Jersey with Massachusetts and Pennsylvania below the model. The high F value indicates that there is unequal variance: the differences between New Jersey 'spread and the other two states are statistically significant.

In the second regression, I changed the dependent variable to the actual amount of the difference of bid and ask price taken absolute. Just like the first model, the second regression only includes Class I REC and only the data after 2008. This model is aimed to further ensure that the differences are not due to percentage. All independent variables are the same as the first one.

The price in CT and MA are significantly higher than MD whereas NJ and PA are only slightly higher than MD. The RPS schedule of New Jersey shows ambitious solar and class 1 renewable energy certificate demands, yet the above regression indicates that New Jersey and

Pennsylvania has the relatively lowest REC prices. The F test also confirms that NJ and PA data do not differ statistically significantly. And similarly the CT data and MA data also do not differ significantly.

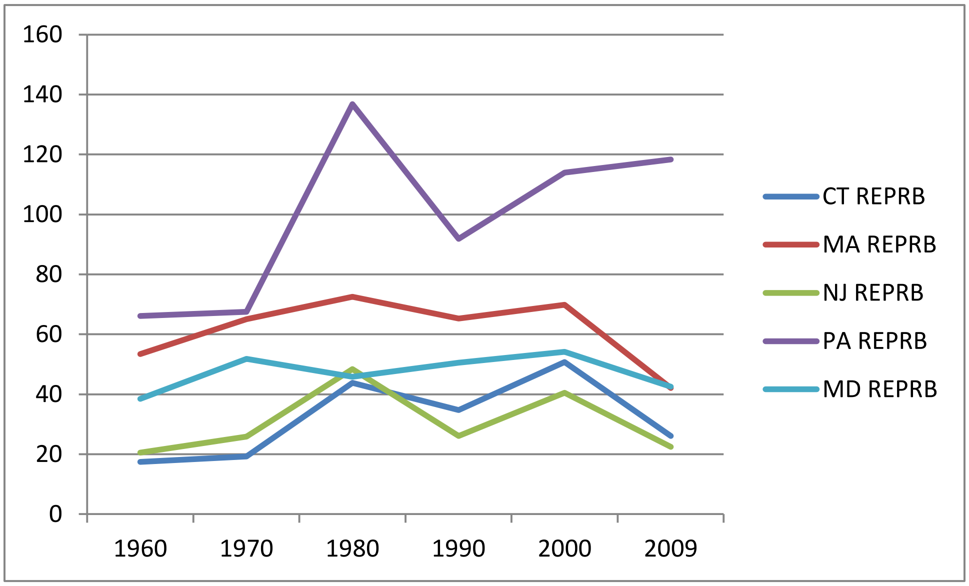


Figure 9. Renewable energy production in CT, MA, NJ, PA, and MD, Trillion Btu. Source: US Energy Information Agency

Conclusion

RPS has emerged as a major approach to promote the development of renewable energy in the US nationally, the importance of these programs will be expected to build on over the coming decade (Wiser et al, 2007). In ideal theoretical situations, RPS should increase the total demand of renewable energy and reduce the financial and management burden of the government (Berry and Jaccard, 2000). REC prices should increase a little by little annually with the annual increase in RPS and the prices should be the same across the states that can trade with each other. But this study shows that this scenario is not applicable to the five states considered in this paper at least. First of all, this study revealed that there is significant difference in the REC prices between states, not only between the states that are in the PJM-GIS and the NEPOOL-GIS but also between the states that are among the same trading system. The REC prices in NEPOOL-GIS are substantially higher than the prices in PJM-GIS. Especially the New Jersey state price seems to be most confusing. In order to answer the question of why there exist such price differences, we need to have a better understanding of how the prices formed. More market data of how the bidding and asking occurred would be crucial for future studies of RPS.

Another observation made in this study is that the bid and ask spread is significantly smaller in Connecticut and Massachusetts than the states in the PJM-GIS. Hence, it seems that the NEPOOL-GIS might be a more active market than the PJM-GIS since wide spread between bids and ask price indicates a thin market.

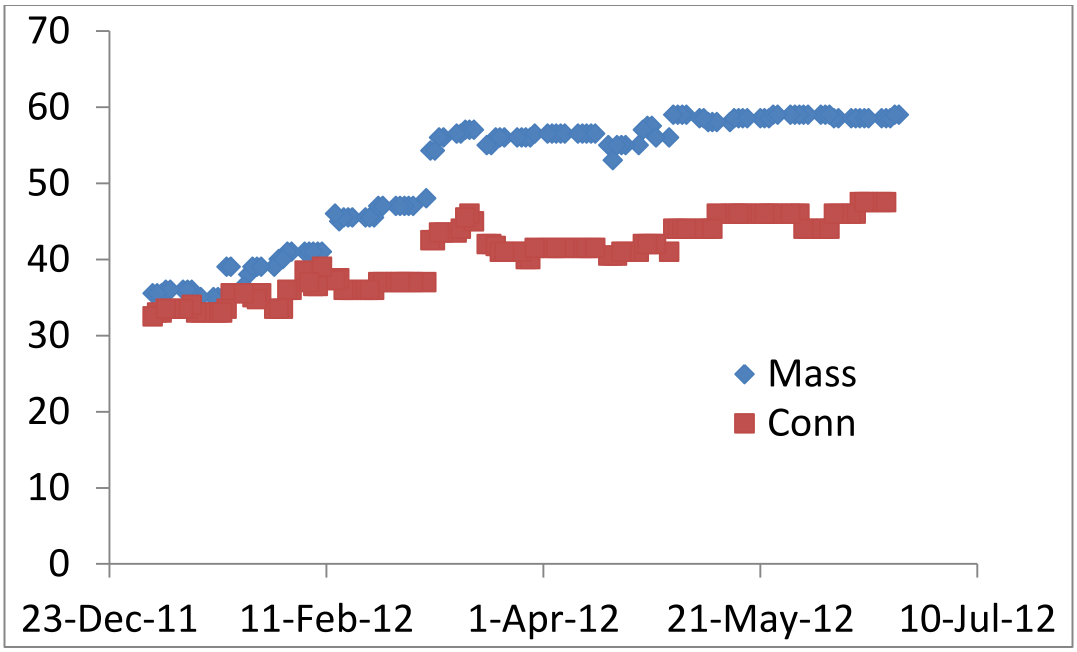
In conclusion, the experience of REC prices in these five states is mixed. From a price stability and market activity angle, the NEPOOL-GIS seem to be superior to the PJM-GIS. Furthermore, whether these RPS programs are actually increasing the overall renewable energy production is also not clear. Figure 9 indicates that Pennsylvania has the largest amount of renewable energy production, and it is the only state in which renewable energy production increased after 2000. Wiser et al argue that RPSs are increasingly motivating renewable energy development since states with RPS have higher renewable energy capacity (see appendix 2). A further look into how the renewable energy productions have changed in these states will be important.

The current literature on the REC price in the US market is limited and therefore it seems to be too early to provide a fine evaluation of the RPS programs based on the performance of

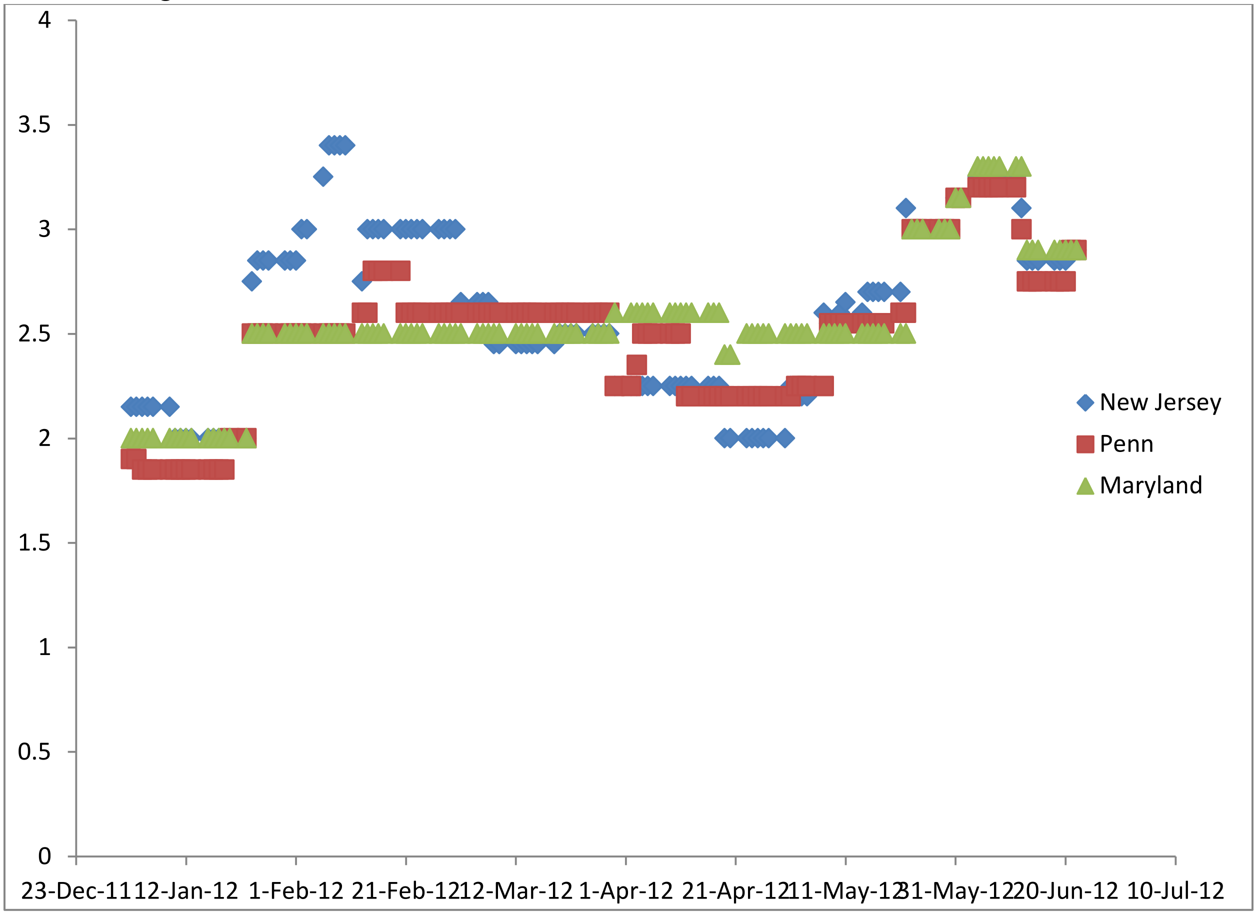
REC markets. A number of researchers believe that FIT is more effective in promoting renewable energy development. Some believe that FIT is superior since it has been argued to be more effective in promoting renewable energy technologies (Rowlands, 2007). These comparisons between RPS and FIT are primarily based on international experience such as a comparison between the RPS in the UK and the FIT in Germany (Mitchell and Connor, 2004). There does not seem to be a sufficient literature on how would FIT or other approach perform in the US.

Finally, from this study I got the impression that there is an inconsistency between state RPS and a large free trading system that covers a large area that varies in geographical characteristics. Business or investors might face challenge in these complex renewable energy markets. Currently it seems that New England could attract more investment into renewable energy development than the PJM-GATS states because of their high REC prices. Moreover, the RPS structures are different at the state level. Take New Jersey as an example, its REC definition, target size and mechanic structure all seem very unclear. Wiser et al. (2008) provide a good summary of the considerations in RPS design. I think these design features might be a cause of the distortion of the prices in the market. Therefore a study that investigates the possibility of re-arranging the trading system will also be valuable.

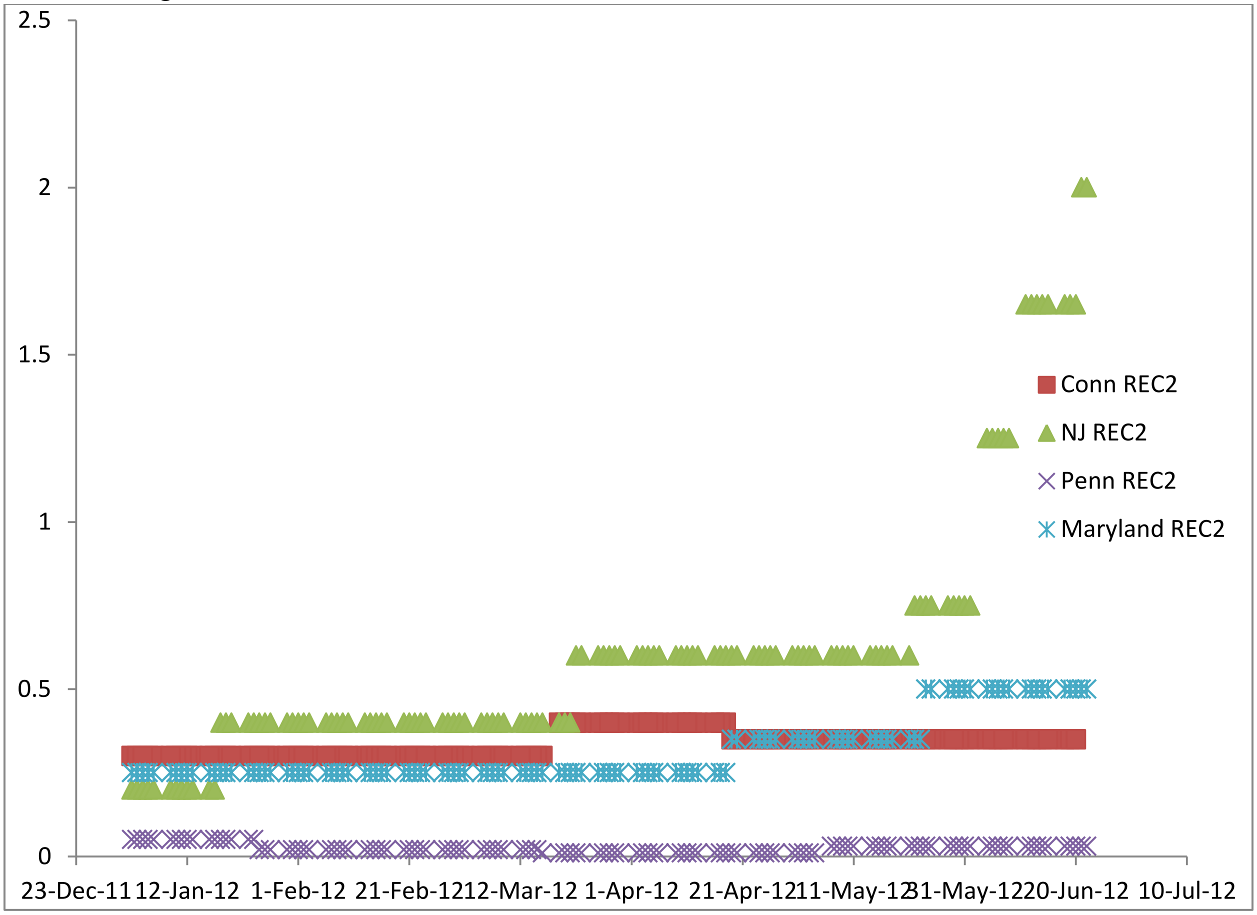
Appendix 1



REC1 Spot Price of Massachusetts and Connecticut in 2012

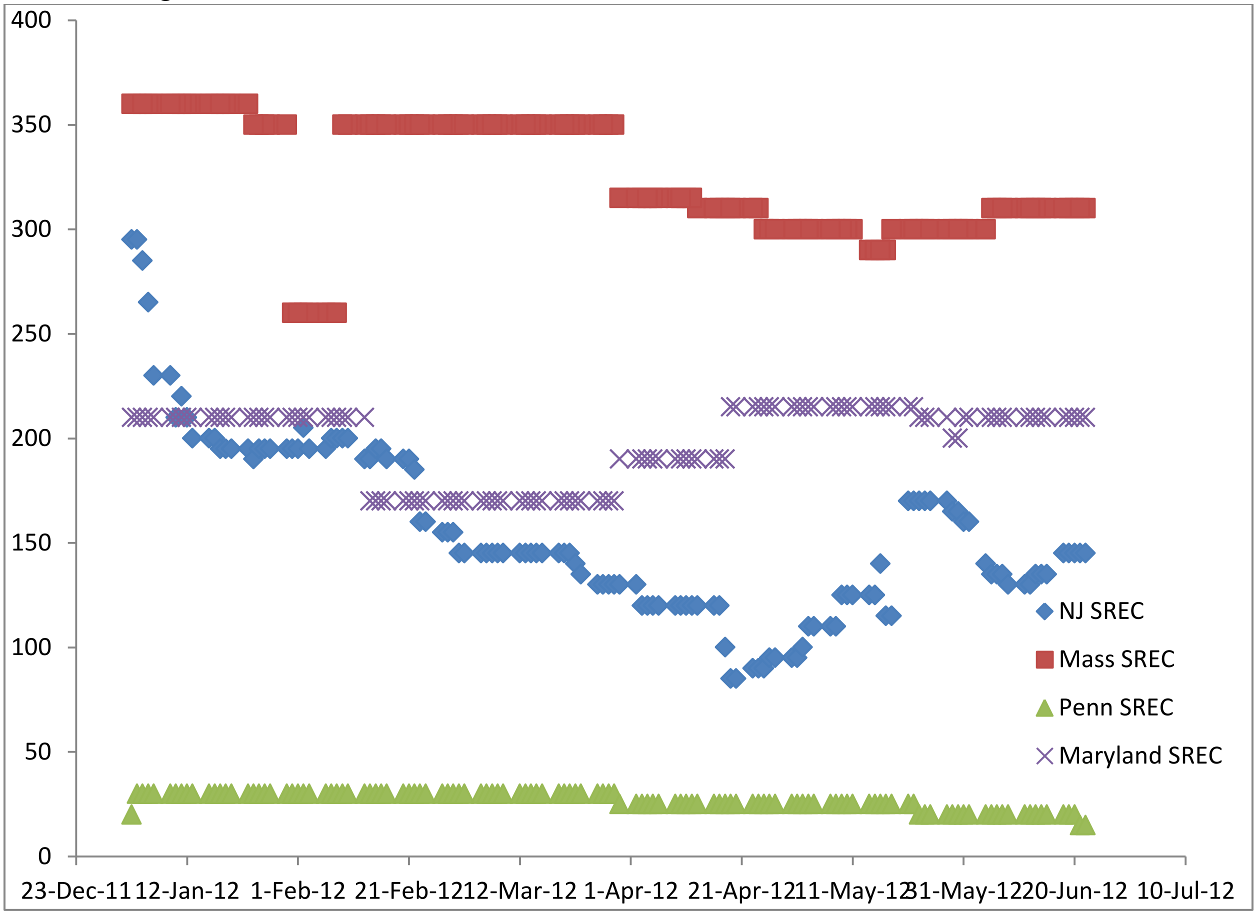


REC1 Spot Price of New Jersey, Pennsylvania and Maryland in 2012



REC2 Spot Price of New Jersey, Connecticut, Pennsylvania and Maryland in 2012[3]

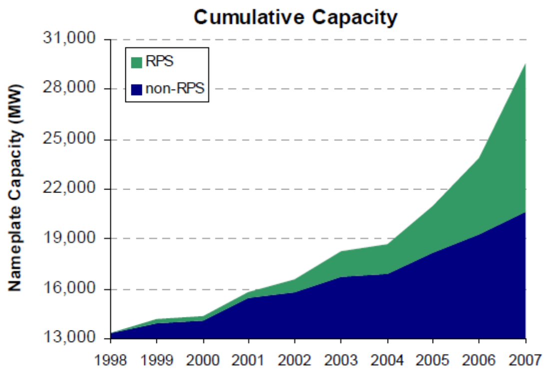
[3] **REC2 Spot Price of Massachusetts in 2012 is always 22.5**

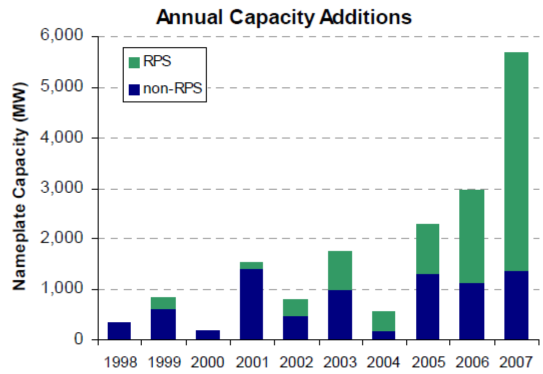


SREC Spot Price of New Jersey, Massachusetts Pennsylvania and Maryland in 2012

Connecticut Solar REC prices data is currently missing.

Appendix 2


Cumulative Capacity
RPS
non-RPS
Nameplate Capacity (MW)
31,000
28,000
25,000
22,000
19,000
16,000
13,000
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007


Annual Capacity Additions
RPS
non-RPS
Nameplate Capacity (MW)
6,000
5,000
4,000
3,000
2,000
1,000
0
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007

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