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JOHN AND WILLIE LEONE FAMILY DEPARTMENT OF ENERGY AND MINERAL ENGINEERING

THE OPTIMIZATION OF THE NEW JERSEY SOLAR RENEWABLE ENERGY CREDIT (SREC) MARKET

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Reviewed and approved* by the following:

Seth Blumsack
Assistant Professor of Energy Policy and Economics
Thesis Supervisor and Honors Adviser

Zhen Lei
Assistant Professor of Energy and Environmental Economics
Faculty Reader

*Signatures are on file in the Schreyer Honors College

ABSTRACT

Solar photovoltaic (PV) installations require some sort of financial incentive due to the relatively high levelized cost of energy (LCOE) that is associated with PV at present. The New Jersey Board of Public Utilities (BPU) introduced the Solar Renewable Energy Credit (SREC) Program to promote solar investment, with one SREC being granted to a producer for each megawatt-hour (MWh) of solar power generated. SRECs can be traded on an open market or retired in order to meet compliance standards. The SREC program is intended to attract investors and market participants to the solar industry to promote alternative energy in the state of New Jersey. However the market has experienced intense price volatility due in large part to heavy SREC oversupply, which is a red flag for investors in any market. It is important for the SREC program to attain a degree of stability if it is to fulfill its goal of incentivizing solar for years to come. The future of the market is uncertain, and creating a better understanding of how it should behave is of great value to installers, load serving entities, and consumers alike.

There have been multiple studies of SREC prices, and this paper looks at the market from a slightly different perspective- SREC production. The amount of solar to be installed in New Jersey must meet the Renewable Portfolio Standard (RPS) requirement, as mandated by the NJ BPU. This paper seeks to answer the question, what SREC issuance quantities for Energy Years (EY) 2014 through 2020 would result in the optimal net discounted profit from the standpoint of the producer? In addition, this paper seeks to find the optimal SREC issuance quantities for EY 2014-2020 that would minimize the net discounted value of total cost to the consumers. To answer these

questions, an optimization model was created that takes into account market parameters as they exist at present, as well as estimated future solar PV LCOE. Future SREC prices were forecasted through an econometric analysis of past SREC prices as a function of annual SREC issuance. It was found that a quadratic regression line captured this relationship quite well. Taking into account future SREC price, policy structure, and future solar costs as constraints, an optimization problem was constructed and carried out for both net discounted cost and net discounted profit.

It was found that in order to maximize the value of the SREC program from the producer's perspective, solar production should be slowed down. This will help to ease oversupply issues, causing SREC prices to slowly recover and even reach SACP levels. The model suggests that lower production and higher prices will help get the most value out of the incentive program, and maximize profits. In order to minimize cost to the consumers, the model suggests halting solar production completely for EY 2014 and 2015, and putting off future SREC production for as long as possible in order to discount costs further into the future. Only until EY 2016 would production be necessary to meet the RPS target, and the model recommends producing an amount of SRECs only equal to the RPS target once banked supply has been exhausted.

The optimal solution in both of these cases is not very likely to occur, as solar production in the state is expected to grow and not decrease. With this in mind, the existing oversupply problem will persist into the future, creating volatility and low prices in the market. While a further investigation of the relationship between price and supply could be beneficial, the future of the program as it pertains to SREC production is

important to understand as well. From a supply perspective, this paper recommends that New Jersey should slow down its production of solar systems and new SRECs, which would cause prices to begin to stabilize and approach the Solar Alternative Compliance Payment (SACP).

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Chapter 1 Introduction

Motivations for Installing Solar Capacity

The demand for solar photovoltaic (PV) capacity exists because there is theoretically an endless supply of potential energy from the sun. Additionally, there are no greenhouse gas emissions associated with solar power generation, such as carbon dioxide (CO_2), sulfur oxides (SO_X), and nitrogen oxides (NO_X). These gasses theoretically contribute to the increase in global temperatures, and nations and states are seeking ways to produce power in a more environmentally friendly way. For these reasons, politicians, members of the energy sector, and ordinary citizens seek out alternative sources of energy. In the coming years the United States is expected to see an increase in alternative energy capacity. Solar PV technology in particular has seen a noticeable decrease in system cost in recent years, as seen in Figure 1.1.

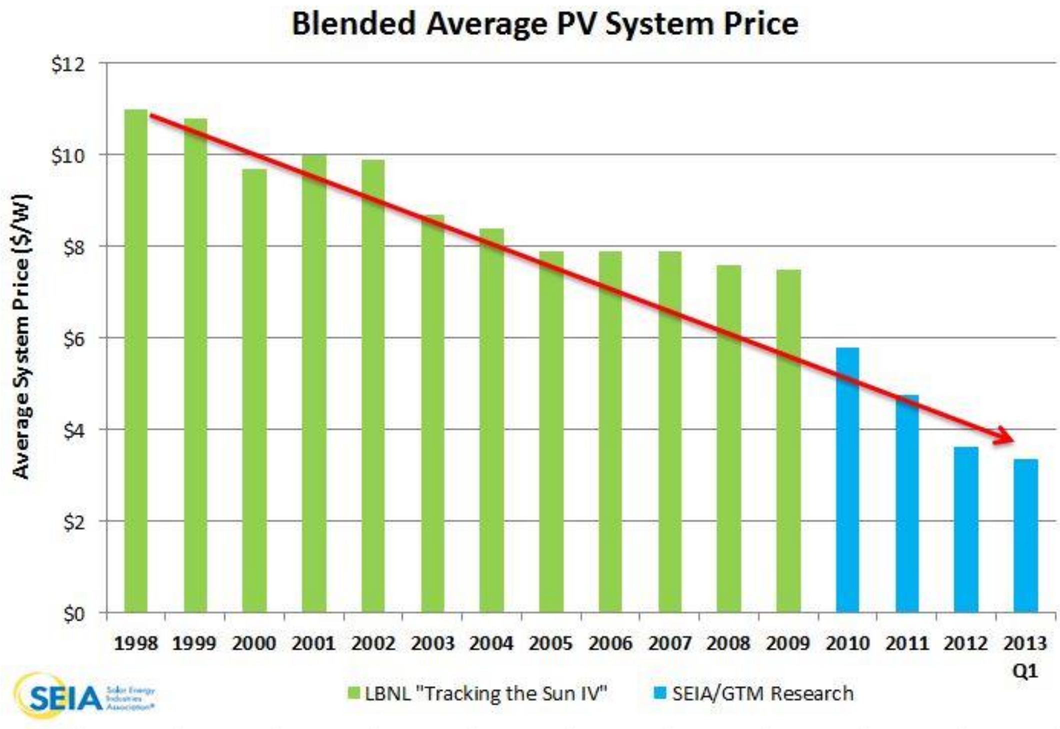


Figure 1.1 the decline in solar system cost 1998-2013 (Source: SEIA)

Solar systems have seen a cost decrease of around 33% since 2011 alone (Solar Energy Industries Association, 2013). With the technology becoming more competitive with traditional sources of electricity, solar energy is expected to experience the highest increase in capacity among alternative energy sources in the coming years, with 46 gigawatts installed by 2040 (around 1,000% of current capacity), as seen in Figure 1.2 (Energy Information Administration, 2014).

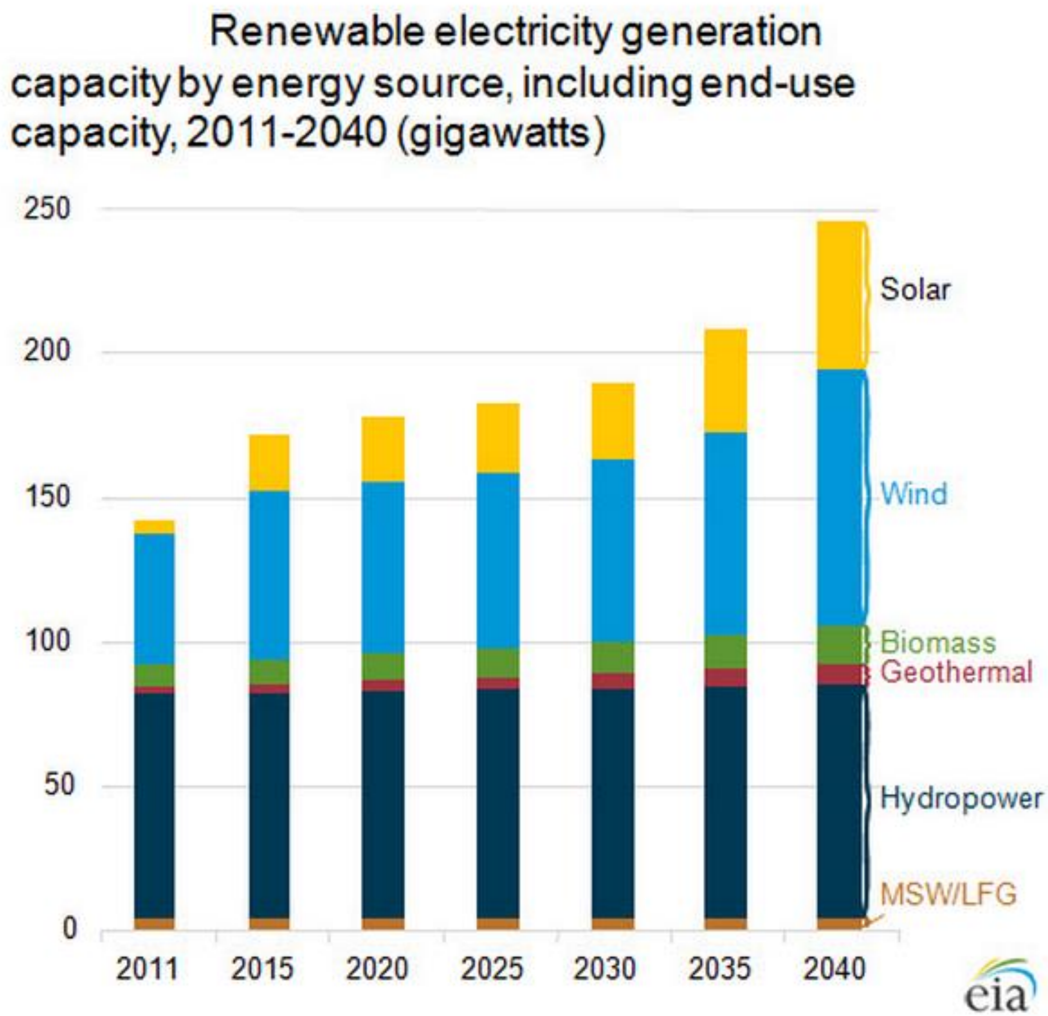


Figure 1.2 U.S. increase in renewable electricity generation 2011-2040 (Source: EIA)

While solar PV technology has a ways to go in terms of efficiency, the solar industry is optimistic that it will see substantial growth in the near future. This is due to both the need for a more environmentally friendly energy sector and decreasing PV costs. For the purposes of this analysis the following LCOE data for solar PV will be used, seen in Table 1.1. It should be noted that an Energy Year (EY) runs from June 1st to May 31st of the denoted year (for example, EY 2009 is from June 1st, 2008 to May 31st 2009).

Table 1.1 Projected Solar PV Levelized Cost of Energy (Source: OpenEI)

Projected LCOE Solar PV	
Energy Year	LCOE ($/kWh)
2010	0.27
2011	0.25
2012	0.25
2013	0.24
2014	0.23
2015	0.22
2016	0.21
2017	0.20
2018	0.19
2019	0.18
2020	0.14
2021	0.16
2022	0.15
2023	0.15
2024	0.15
2025	0.14
2026	0.14
2027	0.14
2028	0.14
2029	0.13
2030	0.12

Solar Renewable Energy Credits (SRECs) and the New Jersey Solar Requirement

Certain states have addressed the need to promote alternative sources of energy so that the energy sector produces less harmful emissions. Most alternative sources of energy, including solar PV, are not presently competitive enough in terms levelized cost of energy (LCOE). The solar industry requires certain incentives in order to bridge the gap between the LCOE of solar PV and that of traditional power sources. For this reason, various states have mandated that load serving entities must obtain certain amounts or percentages of their capacities from solar energy, known as the Renewable Portfolio Standard (RPS) Solar Carve Out. New Jersey is home to one of the most aggressive solar initiatives, and this section is dedicated to explaining the solar incentive market in the state.

Solar Renewable Energy Credits (SRECs) are the denominations used in New Jersey to account for solar generation and compliance with the RPS. The SREC Program, managed by the New Jersey Board of Public Utilities Office of Clean Energy, grants one SREC to a generator for each Megawatt-hour (MWh) of solar power produced. Since its introduction on March 1st, 2004, the program has introduced a new and unique field within the realm of environmental economics (Database of State Incentives for Renewables and Efficiency, DSIRE 2010). Suppliers are required to use the SREC program in order to show that they have complied with RPS requirements lest they submit themselves to penalties (DSIRE, 2010). SRECs can be traded on an open market or retired to reach compliance.

As previously stated, New Jersey has been one of the most ambitious states in terms of its alternative energy goals and RPS requirements. In 2006, the RPS Solar Carve Out was established by the NJ Board of Public Utilities (BPU) at an initial value of 2.21% of total capacity by 2021 (DSIRE, 2014). Since that time, the solar RPS has been revised on multiple occasions, most notably in 2008 and 2012, and the requirement has changed between a percentage of statewide capacity and absolute installed capacity (or number of SRECs). Table 1.2 details the current RPS schedule for the state of New Jersey, which was mandated in the 2012 changes on a percentage basis and goes into effect in Energy Year (EY) 2014. The old RPS is also listed for comparative purposes.

Table 1.2 New Jersey RPS Schedule EY2007-2028 (Source: SRECTrade)

Energy Year	Current RPS (2012 Change)	Current RPS (Approx. # of SRECs)	Old RPS (# of SRECs)
2007	-	-	33,743
2008	-	-	65,384
2009	-	-	130,266
2010	-	-	195,000
2011	-	-	306,000
2012	-	-	442,000
2013	-	-	596,000
2014	2.05%	1,633,394	772,000
2015	2.45%	1,981,386	965,000
2016	2.75%	2,257,365	1,150,000
2017	3.00%	2,499,519	1,357,000
2018	3.20%	2,706,146	1,591,000
2019	3.29%	2,823,990	1,858,000
2020	3.38%	2,944,760	2,164,000
2021	3.47%	3,068,519	2,518,000
2022	3.56%	3,195,327	2,928,000
2023	3.65%	3,325,250	3,433,000
2024	3.74%	3,458,351	3,989,000
2025	3.83%	3,594,697	4,610,000
2026	3.92%	3,734,355	5,316,000
2027	4.01%	3,877,394	-
2028	4.10%	4,023,884	-

The RPS requirement of 4.10% by EY 2028 is considered one of the most aggressive solar initiatives in the United States (DSIRE, 2014). For the purposes of this analysis, RPS percentage values for EY 2014-2028 have been converted to approximate

SREC quantities for future energy years. It should also be noted that the requirement for EY 2014 (approximately 1,633,394 SRECs) is significantly greater than that of EY 2013 (596,000 SRECs). This increase was one of the most notable changes that came with the 2012 amendments to the schedule, which go into effect in EY 2014. The market was greatly oversupplied in EY 2012, and the RPS increase in the short term is intended to address this issue. The following Figure 1.3 shows the difference between the old and new RPS schedules.

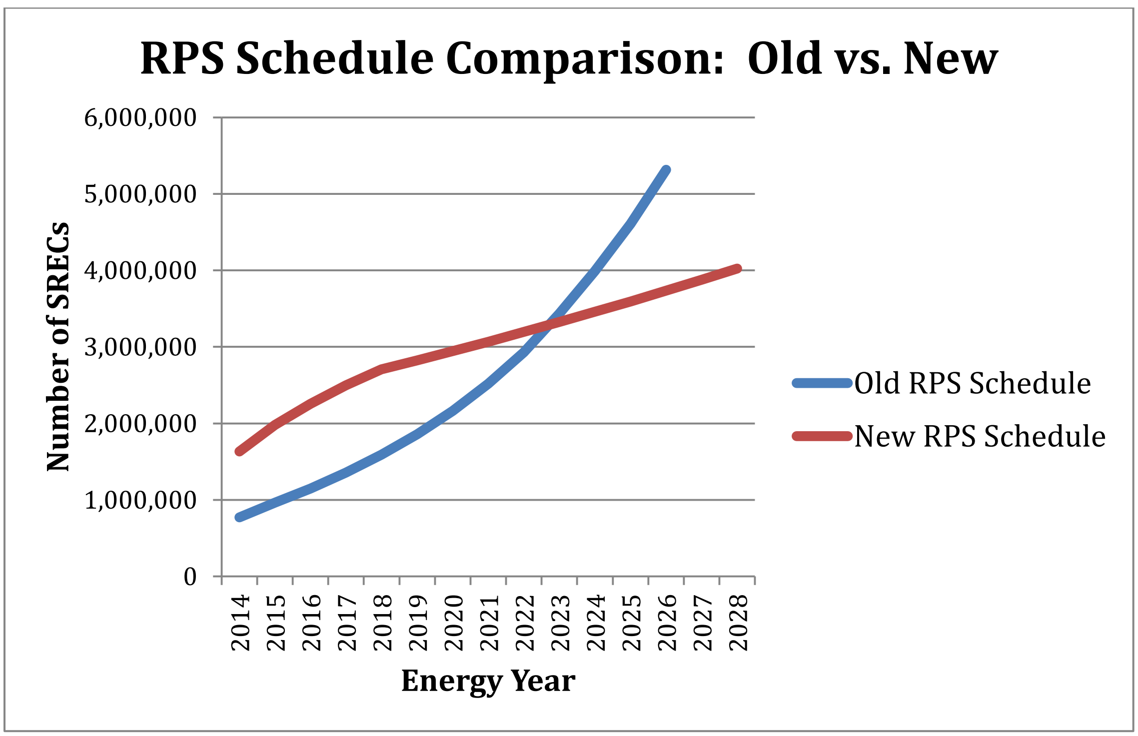


Figure 1.3 New Jersey RPS Schedule Comparison (Data Source: SRECTrade)

While the new schedule mandated a sudden increase in the requirement, over the long run the old schedule had a far higher RPS. An analysis of market oversupply in recent energy years will be discussed.

The Solar Alternative Compliance Payment (SACP) and SREC Banking

As mandated by the New Jersey BPU, utilities within New Jersey must meet the RPS schedule through the NJ SREC Program. If they fail to obtain sufficient percentages of their power from solar PV, the Solar Alternative Compliance Payment (SACP) is levied onto the load serving entity in question, on a $/MWh basis. The SACP Schedule through 2028 is listed in Table 1.3.

Table 1.3 New Jersey SACP Schedule 2009-2028 (Source: SRECTrade)

Energy Year	SACP ($/MWh)
2009	$711
2010	$693
2011	$675
2012	$658
2013	$641
2014	$339
2015	$331
2016	$323
2017	$315
2018	$308
2019	$300
2020	$293
2021	$286
2022	$279
2023	$272
2024	$266
2025	$260
2026	$253
2027	$250
2028	$239

Because the SACP is levied on a $/MWh basis, it acts as the effective price cap for SREC trades in the state. As seen in the Table 1.3, the EY 2014 SACP is significantly less than that of EY 2013. This schedule is also is in line with the NJ BPU intention to gradually decrease the importance of the SREC program. The thinking is that the solar industry will one day be able to survive without incentives in the form of SRECs, although this change will occur over a long period of time.

Banking is a feature of the SREC that dictates the number of energy years for which one SREC may be used for compliance. The duration, or lifetime, of a SREC has been changed along with the RPS and SACP, most recently in 2012. The original SREC Program did not permit banking, but in 2008 a three-year lifetime was introduced. In 2012, along with many other changes to the SREC program, five-year lifetimes were introduced (Coulon, Khazaei, Powell, 6). One other feature of the program that was altered was the true-up period, which is defined as the period of time between the end of the energy year and when suppliers must present their SRECs or pay the SACP. At present, the true up period is June 1st to November 30th, giving load-serving entities six months after the energy year to meet compliance standards.

The New Jersey SREC market is unique and still relatively young. There have been many changes to the structure of the market, and prices have behaved in a very volatile fashion.

Chapter 2 New Jersey SREC Prices and Market Oversupply

History of New Jersey SREC Prices

Analyzing the SREC market history can be somewhat tricky due to the number of changes to the market structure. Despite this it is important to understand how the market has functioned in recent years in order to attempt to forecast its future.

The SREC Market has displayed a large degree of volatility in its short history, as seen in Figure 2.1.

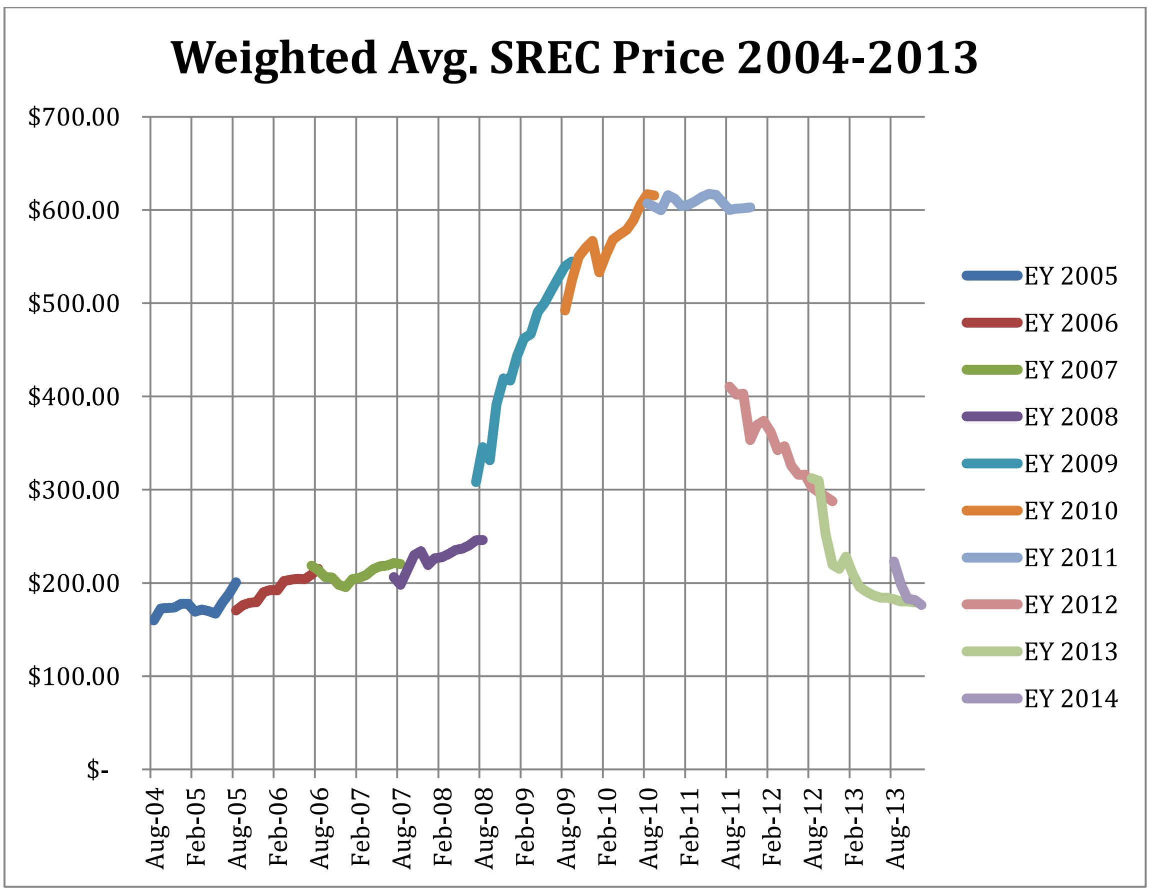


Figure 2.1 Weighted Average SREC Price 2004-2013 (Data Source: NJ Clean Energy Program)

SRECs can trade at greatly different prices in a given period, so the weighted average price for each month was used for Figure 2.1. The SREC price was relatively stable at around an average of $240 in June of 2008, and then began to rise to well over $600 by the middle of 2011. In EY 2011 the SACP was $675, so prices were operating at or near the price ceiling. By late 2013, the average price had fallen below $180 (NJ Clean Energy Program). The market crash has been a subject of much investigation and speculation. For most of the market's lifetime it has been slightly under-supplied (until EY 2012), resulting in compliance penalties and very high prices, near the SACP.

Influences on SREC Prices

So what are the factors that influence the price of a SREC? There have been multiple investigations of this question that go into far more depth than this paper, as this paper has a different focus. However, it is important to understand the relationship between SREC prices and the market parameters, as well as the reasons for observed price volatility.

Dr. Frank Felder, in his paper "Reducing Price Volatility of New Jersey Solar Renewable Energy Credits", attributes most of the price volatility to the current RPS structure, which results in a vertical demand curve.

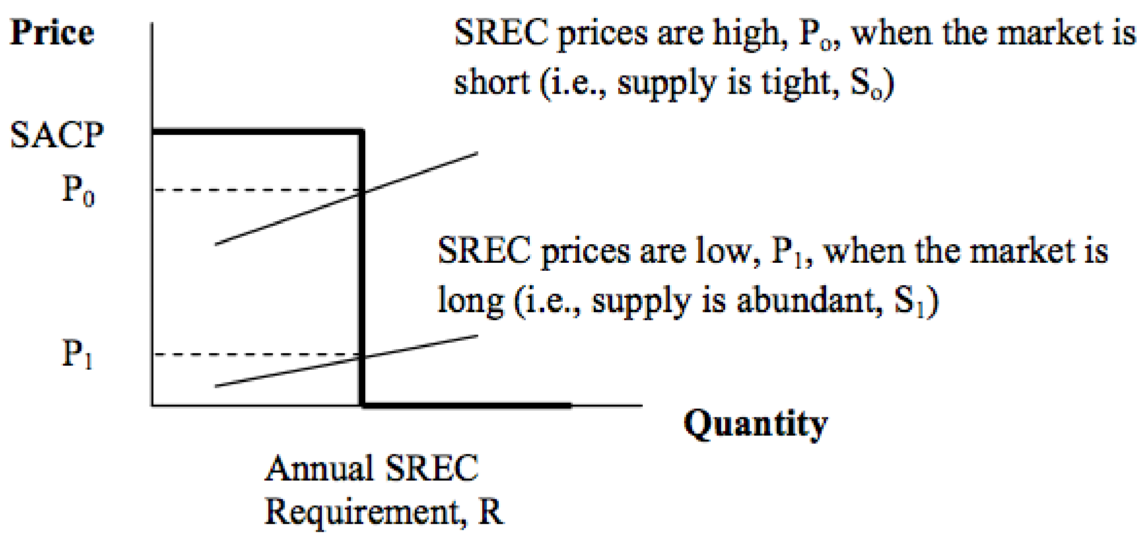


Figure 2.2 The Vertical Demand Curve of the NJ SREC Market (Felder, 3)

Because of an established RPS schedule the demand level is fixed and "any significant change in supply will cause prices to change significantly" (Felder, 1). A minor decrease in supply, for example, can drive prices up to levels near the SACP. Dr.

Felder's paper focuses almost exclusively on market structure as a SREC price determinant.

Other reports investigate SREC prices from different perspectives. In his thesis titled "Here Comes The Sun: An Investigation of Solar Renewable Energy Credit Prices in the U.S.", David Manning of George Washington University found a relationship between price and a number of factors outside of policy structure. For example, steel billets are major components of wind turbines, and Manning explored the impact of steel billet prices on SREC prices, under the logic that wind turbines and solar panels are potentially substitute goods. In his correlation analysis, he discovered a "statistically significant relationship between steel billet price and SREC price in multiple trials" (Manning, 4). In addition to steel billets, Manning also observed that SREC prices tended to increase with falling polysilicon prices, which is somewhat reverse logic given that polysilicon is the major raw material for solar PV panels. This potentially signals that falling polysilicon prices lead investors to assume more solar investment is on the way, driving up the SREC price (Manning, 6). In essence, Manning's paper examines SREC price influences outside of policy structure and suggests that policy structure is not the sole determinant of prices.

For the purposes of this paper, policy structure and a basic application of supply and demand economics will be used to analyze the SREC market. While Manning's work is valuable in understanding SREC price behavior in particular, a more in depth study is needed to factor in outside economic conditions. With this in mind, let us begin to understand the basics of what occurred in the years up to and including EY 2012 within the SREC market. As previously stated, the supply of SRECs operated below the

RPS until EY 2012, creating an artificially high price that made solar investment very attractive. High SREC prices created a higher than intended incentive to enter the SREC market, and EY 2012 saw a great number of new installations in New Jersey. The Number of SREC issuances have grown an average of 91% per energy year since EY 2008. The monthly increases in SREC issuances are seen in Figure 2.3.

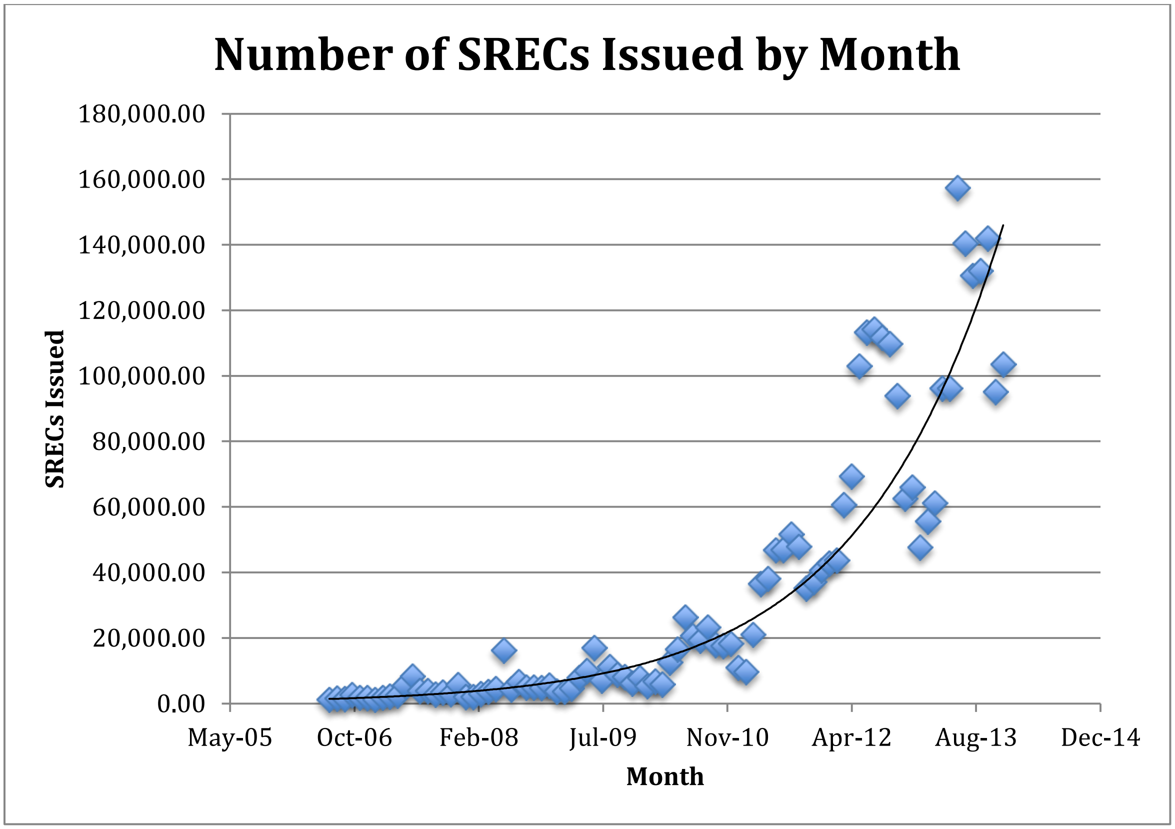


Figure 2.3 SREC Issuance by Month EY 2006-2-13 (Data Source: SREC Trade)

This exponential growth was assuredly unexpected from the NJ BPU's perspective. While the old RPS schedule (as seen in Table 1.2) was linear, the growth in SREC issuances has been exponential, as seen in Figure 2.3. The established RPS schedule, which was linear, was not suited for such an increase in SREC issuances, and the market outgrew its requirement too quickly, resulting in massive oversupply. EY 2012 was the first year that had no penalty payments, because SREC issuances were so much higher than the RPS. Figure 2.4 compares the growth in SREC issuance to the old RPS schedule.

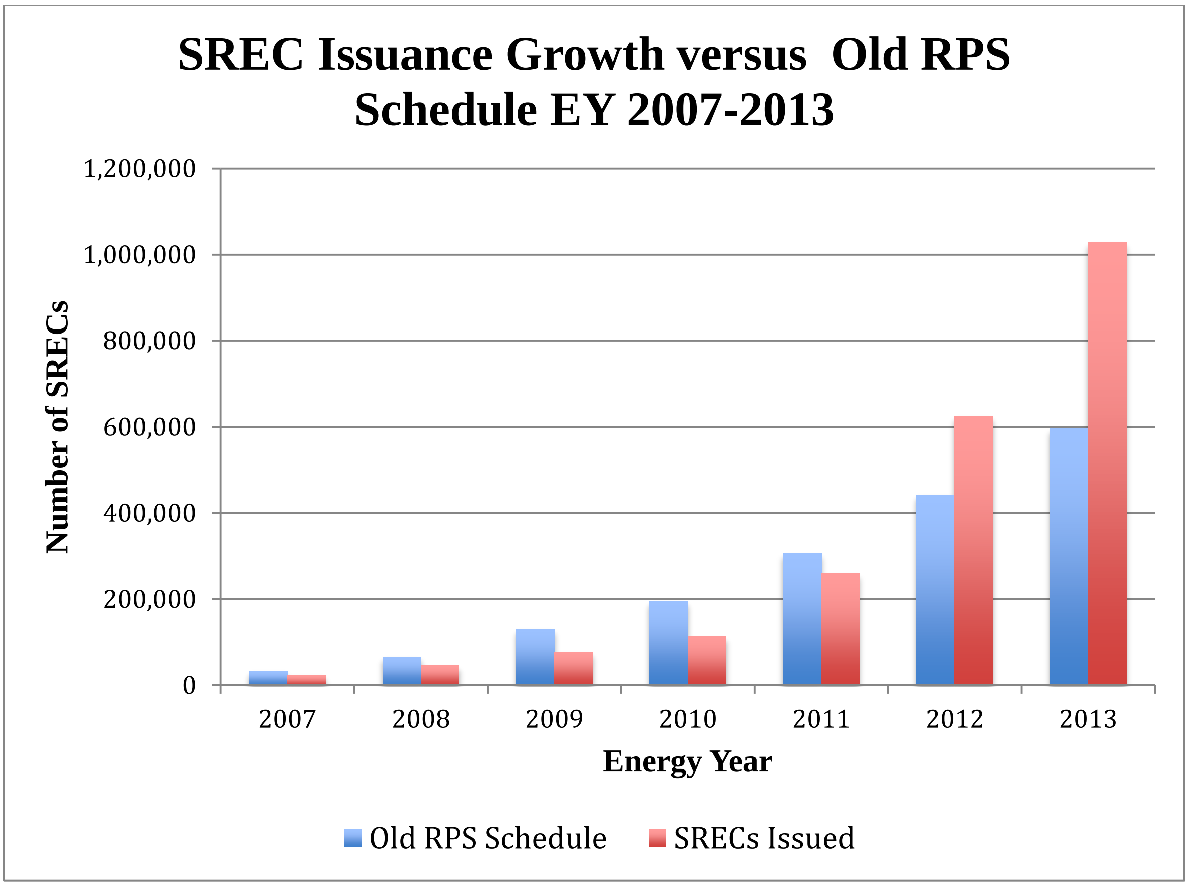


Figure 2.4 SREC issuance growth compared to original RPS schedule (Data Source: SRECTrade, NJ Clean Energy Program)

The EY 2013 market was oversupplied by approximately 431,000 SRECs, or 172% of the RPS for that year (SRECTrade). In 2012 the NJ BPU greatly increased the RPS in the short term, which goes into effect in EY 2014. An undersupplied market led to SREC prices higher than intended by the original policy structure. The market experienced a shock as a result of this influx of solar capacity in the state and prices fell dramatically as supply began to exceed demand, as seen in Figure 2.5.

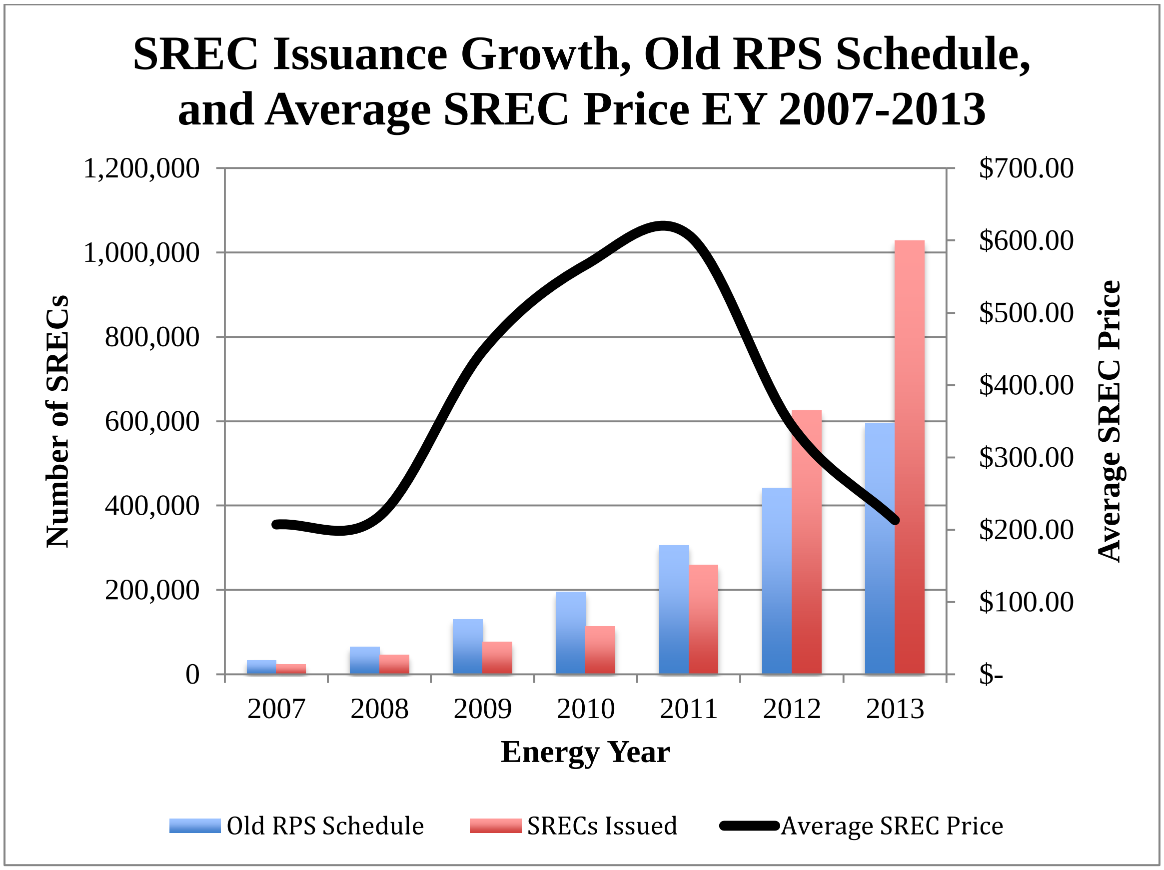


Figure 2.5 SREC Issuance, Old RPS Schedule, and Average SREC Price (Source: SRECTrade, NJ Clean Energy Program)

EY 2012 and 2013 experienced exponential growth in SREC issuances, and prices reacted accordingly. This is important to keep in mind moving forward.

Future Market Oversupply

The current SREC market structure dictates that SRECs have lifetimes of five years. Because of this, oversupply in certain energy years can lead to the market remaining in such a state for future energy years. For example, let us account for the SRECs issued up to and including EY 2013, and assume that no additional solar is installed in the state after EY 2013. The New Jersey SREC would be able to supply itself with existing supply through EY 2015, and also fulfill about half of the requirement for EY 2016.

Table 2.1 The Oversupplied NJ SREC Market

Energy Year	*RPS Requirement*	*Incremental Target*	*New SRECs*	*Banked SRECs in EY*	*Total SRECs Banked*
2009	130,266	130,266	77,910	-	-
2010	195,000	64,734	130,161	65,427	65,427
2011	306,000	111,000	285,415	174,415	350,842
2012	442,000	136,000	713,271	577,271	887,686
2013	596,000	154,000	1,082,009	928,009	1,659,280
2014	1,707,931	1,111,931	-	-	547,349
2015	2,071,803	363,872	-	-	183,477
2016	2,360,376	288,573	-	-	-

Table 2.1 displays just how oversupplied the NJ market is. The RPS requirement, as previously stated, represents the total solar capacity needed to comply with state mandates. The Incremental target represents the increase in the RPS requirement from the previous energy year. New SRECs are the solar generated within the energy year. Banked SRECs in EY are the number of SRECs produced in excess of the RPS for that EY, and Total SRECs Banked represent how many total SRECs are in supply (including SRECs leftover from previous energy years thanks to banking).

The most important relationship in Table 2.1 is the Total SRECs Banked versus the Incremental Target. With no solar produced (no new SRECs generated from EY 2014-2016) the market would be able to supply itself until the number of Total SRECs Banked reaches zero. This displays the extent to which SREC issuances outstripped the RPS, and thereby demand. This concept does not take into account SREC price but is important to understand the current state of SREC supply in the market.

Chapter 3 New Jersey SREC Issuance Problem

Attempting to understand the future performance of the NJ SREC market is information that could be of great interest to installers, residential PV owners, and suppliers alike. The goal of the NJ BPU in creating the SREC program was to incentivize the use of solar power throughout the state, and price volatility jeopardizes that incentive. When a solar system is installed in New Jersey, the owner or installer includes the value of future SRECs in any expected financial returns. Dr. Frank A. Felder, Director of the Center for Energy, Economic & Environmental Policy at Rutgers University, notes that volatile prices lead to "higher investment costs because investors associate price volatility with increased risk" (Felder, 1). He also points out that price volatility can impact the very structure of the SREC program. "Volatile SREC prices also have adverse public policy consequences. Their price volatility masks the true cost of solar making it difficult for policymakers to evaluate solar policies. When prices spike, there are calls to change solar policies to reduce electricity rate impacts because at the end of the day retail electricity consumers pay for SRECs, and when prices fall, then solar developers and producers insist on changes to push prices back up" (Felder, 4). In essence, volatile prices lead to policy being whipped back and forth as it reacts to drastic increases or drops in price. This can threaten the effectiveness of the SREC program entirely.

There have already been various studies on price volatility and market performance. Dr. Felder's "Reducing Price Volatility of New Jersey Solar Renewable Energy Credits" from October of 2011 provides an analysis of the market and what factors influence the SREC price. Felder theorizes that to reduce volatility "a downward sloping demand curve should be introduced" by implementing a sliding scale requirement, as opposed to a single requirement for the energy year. Figure 3.1 is "one such possible way of this by keeping the maximum amount that ratepayers would pay constant, and therefore the maximum amount of revenues the industry could earn, the same" (Felder, 5).

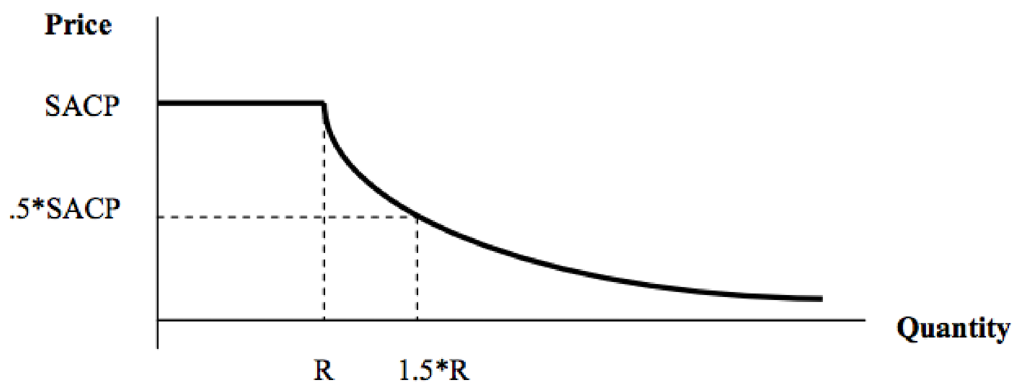


Figure 3.1 Introducing a Downward Sloping Demand Curve (Analysis and Graphic by Dr. Frank Felder)

In Figure 3.1, Felder depicts an example where the SREC production in an energy year has surpassed the RPS requirement by 50%. Accordingly, the SACP adjusts by decreasing 50%. He argues that a single and scheduled requirement and penalty makes the demand curve far too vertical, increasing volatility.

A paper by Michael Coulon, Javad Khazei, and Warren B. Powell entitled "Smart-SREC: A Stochastic Model of the New Jersey Solar Renewable Energy Certificate Market" also investigated volatility, and introduced a stochastic model of SREC prices, taking into account parameter sensitivity and generation responses to prices. These papers have provided invaluable insight to the market prices. Despite all of this, creating a deeper understanding of the SREC market remains beneficial.

With this in mind, I sought to find the SREC issuance quantity, through EY 2020, that optimized the SREC program from a statewide net discounted value of profits standpoint (at current market parameters). The question addressed was; how much solar should be installed so that net discounted profit is maximized, all while meeting the current RPS schedule? Additionally, I sought to answer the question, how much solar should be installed so that net discounted cost to the consumer is minimized, while still meeting the current RPS schedule? This is also an optimization problem, and one that analyzes the total discounted cost of solar from the consumer's perspective, as opposed to profit from the producer's perspective.

These two questions were addressed through the creation of a model that included observed SREC market data from EY 2009-2013, and forecasted data through EY 2020. This model took into account observed and future relationships between SREC supply and price, current RPS schedules, and future solar PV LCOE. While this exercise was not directed at forecasting future SREC prices, it will help to develop a further understanding of how the SREC market should function in terms of solar capacity production and help to analyze market parameters from a different angle.

Chapter 4 The NJ SREC Market Optimization Model

One way to look at this problem is to imagine that there is one person acting as the one and only solar installer in all of New Jersey- they are in charge of the entire solar industry in the state. How much solar should they install so that they come away with optimal profit? This is the question being addressed by the issuance optimization model. Additionally, a second optimization exercise is carried out in the form of a SREC cost minimization problem. How many SRECs should be produced in order to minimize the net present value of the total cost to consumers, and yet still meet RPS targets in each energy year? This analysis finds optimal SREC productions from the perspective of both the consumer and the producer.

Optimization Model and Objective

This chapter is dedicated to explaining the optimization problem, along with all of its parameters. Optimization problems are effective tools for finding the ideal values for a particular set of variables in order to maximize or minimize an objective value. These calculations have three parts to them, both in general and within the Microsoft Excel Solver (the tool used to carry out the calculations). These include the objective, the decision variables, and the constraints. The Microsoft Excel Solver is an application that simplifies the process of carrying out an optimization problem, as it solves for a specified goal given a set of constraint inputs. Each optimization problem is different, given the objective being pursued.

The objective of this optimization is to define the amount of SREC investment over the course of energy years 2014 through 2020 such that the value of the SREC market is maximized in the first exercise, and cost is minimized in the second. This objective is constrained by the Solar Alternative Compliance Payment (SACP), as the price (P) cannot surpass this value. Additionally, the amount of SREC production in a given energy year must always equal or surpass the RPS target as mandated by the NJ BPU. The price constraint was projected through EY 2020 based econometric analysis of historical SREC prices and issuances. The discount rate used for all calculations was 10%. The following equations represent the parameters of the problem.

Equation (1) represents the objective of the optimization, and equations (2) through (6) represent the constraints on the objective.

For the variables:

S_i= SRECs Issued for EY *i*
$S_{TOTAL,\,i}$= Total SREC Supply for EY *i*
$S_{TARGET,\,i}$= RPS Target for EY *i*
r = Discount rate, 10%
P_i = SREC avg. weighted price in EY *i*
C_i = Cost of producing an SREC in EY *i*

(1) Maximize: $$\{S_{2014}, S_{2015}, \ldots, S_{2020}\} \sum_{i=2014}^{2020} \frac{(S_i \times P_i)-(S_i \times C_i)}{(1+r)^i}$$

Such that:

(2) $P_i = f(S_i)$ i= {EY 2014, EY 2015,…, EY 2020}

(3) $S_{TOTAL,i} = S_{i-1} + S_i$ i= {EY 2014, EY 2015,…, EY 2020}

(4) $S_{TOTAL,i} \geq S_{TARGET,i}$ i= {EY 2014, EY 2015,…, EY 2020}

(5) $S_{TOTAL,2020} = S_{TARGET,2020}$

(6) $S_i \geq 0$ i= {EY 2014, EY 2015,…, EY 2020}

Constraints for the Model

Let us begin with constraint (2), which represents the econometric analysis of price as a function of SRECs issued.

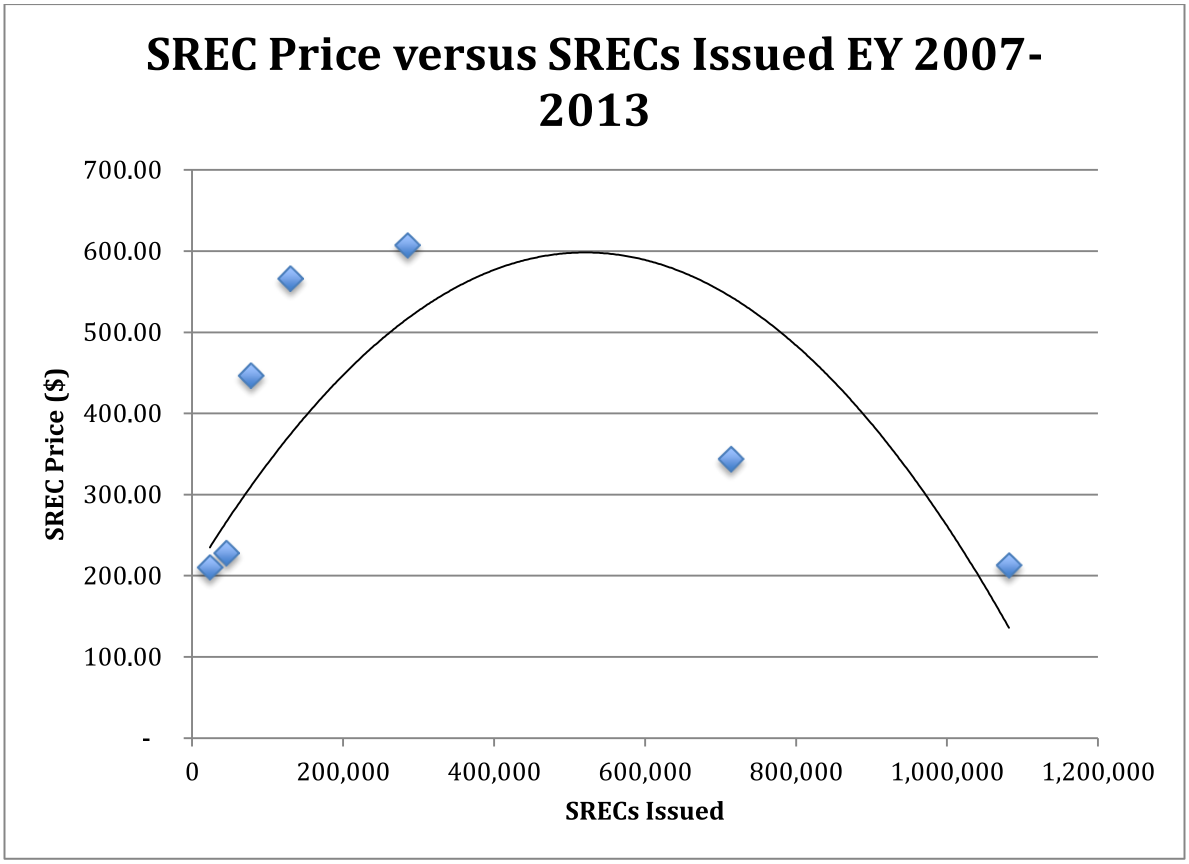


Figure 4.1 SREC Price versus SRECs Issued (EY 2007-2013)

Using past SREC price and issuance data, future SREC prices can be determined endogenously from within the optimization model. Figure 4.1 displays the relationship between SREC price and SRECs issued through EY 2013, including the quadratic regression line. This relationship was best represented in a quadratic nature, although a linear regression was also tested. It was clear that a linear relationship was not present, as price clearly grew in exponential fashion when related to SREC issuances. A second-degree polynomial resulted in the most acceptable R^2 value, and was used for the regression line. This line held the following equation.

$$P_i = -1 \times 10^{-9}(S_i)^2 + 0.0015(S_i) + 200$$

The relationship I found between SRECs issued and SREC price was best represented by the aforementioned equation. The next step was to introduce this function into the optimization model, so that prices could be forecasted appropriately. Therefore, the prices in the following Table 4.1 are based off of the optimized SREC issuances, seen in the following chapter.

Table 4.1 SREC Price Forecasted Through EY 2020

Energy Year	Prices ($/SREC)
2009	446.78
2010	566.28
2011	607.47
2012	343.85
2013	213.13
2014	339.00
2015	211.53
2016	201.08
2017	315.00
2018	308.00
2019	300.00
2020	293.00

Constraint equation (3) represents the condition that total SREC supply in a given energy year is equal to the total supply from the year previous, plus the new SREC production. In other words, excess supply is added to the total SREC supply for the following energy year.

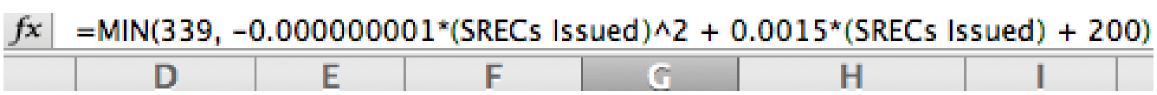
Constraint equation (4) represents the condition that total SREC supply in a given energy year must be greater than or equal to the RPS requirement in that energy year.

This ensures the model leads to enough SREC production to meet annual compliance, as it is assumed that market participants would seek to avoid the SACP.

Constraint equation (5) ensures that total SREC supply in EY 2020 is exactly equal to the RPS target in EY 2020.

Constraint equation (6) is the non-negativity clause for the model, because SRECs cannot be destroyed and supply for a given energy year can never be negative.

Another aspect of the price that must be taken into account is the SACP, seen previously in Table 1.3, which acts as the effective price cap. Within the model, the price was not permitted to surpass the SACP for that respective energy year because load-serving entities generally would not pay for a SREC at a price higher than the SACP. This was enforced through a minimum (MIN) function in excel, which chooses the smaller of two values in a given cell (either the value of the price function or the SACP, in this case). For example, the price equation for EY 2014 read as follows, including the $339 SACP for that EY (cell reference was replaced with “SRECs Issued”).



The Incremental Target is the number of SRECs added to the SREC total requirement from the previous year, represented by the following equation where *t* is the energy year in question.

$$Incremental\ Target(i) = (RPS\ Target)_i - (RPS\ Target)_{i-1}$$

Additionally, the model accounts for both SRECs Banked in the EY and Total SREC Supply. In the above optimization problem, S_{TOTAL} represents the total SREC supply in the market. If SRECs produced exceeds the target in a given year, the extra production is accounted for and available for the following energy year's requirement.

Cost represents the LCOE of solar PV, on a $/MWh basis as forecasted on the OpenEI Database. These values were discussed in Chapter 1, Table 1.1. This value is the cost to install solar on a per SREC basis (per MWh basis). Total cost for an energy year is defined as the number of new SRECs generated multiplied by the PV LCOE (on a $/MWh basis) for that energy year.

$$Total\ Cost(i) = (PV\ LCOE)_i \times S_i$$

Decision Variables

In the hypothetical situation where someone is the only solar installer in all of New Jersey, the variable that they fully control is the amount of solar produced in each EY, also known as the number of SRECs generated or issued. This is our decision variable- the final input used to calculate all other variables and ultimately optimize net discounted profits. In the model, SREC issuances in each EY are found through the solver. The results will be seen in following chapter, as they are directly related to the optimization objective.

To calculate the net discounted profit for the SREC program through EY 2020, we must first calculate the cash flow for each energy year, given the number of SRECs issued as determined by the solver. The general equation for profit in an energy year *i* is represented as follows (with cost per SREC represented by the variable "C").

$$(Total\ Profit)_i = (Total\ Revenue)_i - (Total\ Cost)_i$$

$$(Total\ Profit)_i = (S_i \times P_i) - (S_i \times C_i)$$

With the calculation for Total Profit in each energy year, the net present value of profits can be calculated and the model can be optimized. As a reminder, the net discounted value of profits equation in the context of the SREC model reads as follows.

$$\{S_{2014}, S_{2015}, \ldots, S_{2020}\} \sum_{i=2014}^{2020} \frac{(S_i \times P_i)-(S_i \times C_i)}{(1+r)^i}$$

This equation is our objective, and can be solved once all constraints are in place. The solver is implemented to calculate the optimal SREC issuance rate and thereby the optimal net discounted profit. The following Figure 4.2 is a screenshot as it appears in the model within Microsoft Excel.

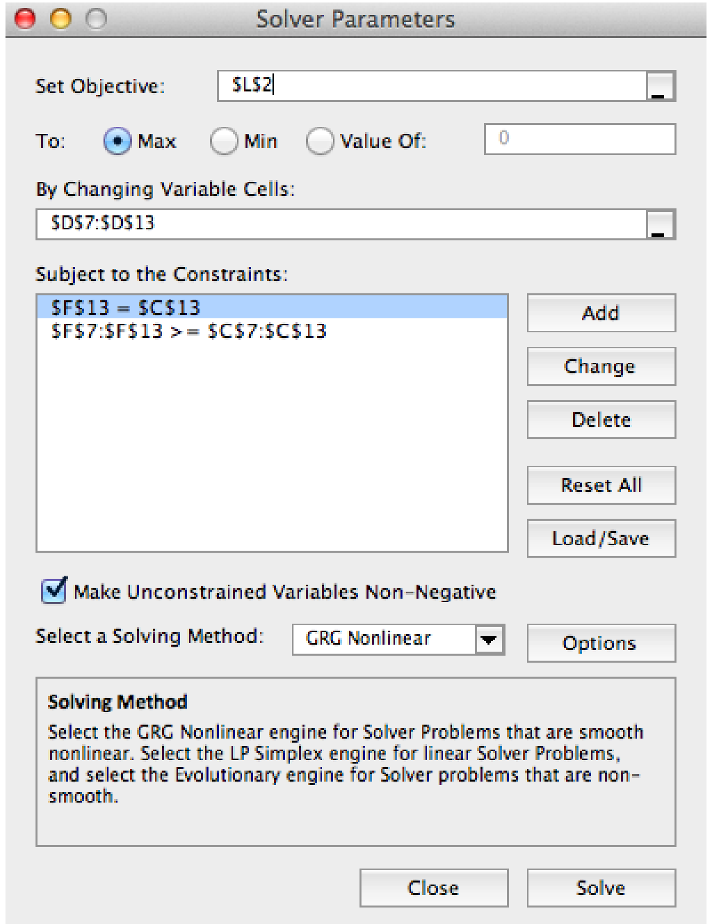


Figure 4.2 Solver Parameters in Excel

The objective cell is the Net Discounted Profits. The goal is to maximize this value, so “max” has been selected. The variable cells to be changed are the SRECs issued in EY 2014-2020 in the model.

Two primary parameters must be physically inputted in order for the model to meet the requirements of the NJ policy structure, as seen in the field titled “Subject to the Constraints”. First, for the purposes of this model, the number of SRECs produced in 2020 must exactly equal the incremental target for 2020.

$$S_{TOTAL,2020} = S_{TARGET,2020}$$

Again, this is a condition that will ensure market optimization for the timeframe being considered in the model.

Second, the total supply of SRECs in a given energy year must always be greater than or equal to the incremental target in that year, in order to meet the RPS requirement.

$$S_{TOTAL,i} \geq S_{TARGET,i}$$

As stated earlier, the solver was used in a non-linear capacity. This is why the Solving Method "GRG Nonlinear" has been selected.

Cost Minimization Problem

One other exercise that provides useful analysis is a SREC Cost minimization problem. This optimization problem has the same decision variables and constraints as the aforementioned optimization problem, but minimizes the cost to consumers instead of maximizing profit for producers.

For the variables:

S_i= SRECs Issued for EY *i*
$S_{TOTAL,\ i}$= Total SREC Supply for EY *i*
$S_{TARGET,\ i}$= RPS Target for EY *i*
r = Discount rate, 10%
P_i = SREC avg. weighted price in EY *i*
C_i = Cost of producing an SREC in EY *i*

(1) Minimize: $$\{S_{2014}, S_{2015}, \ldots, S_{2020}\} \sum_{i=2014}^{2020} \frac{(S_i \times C_i)}{(1+r)^i}$$

Such that:

(2) $P_i = f(S_i)$ $\quad$ i= {EY 2014, EY 2015,…, EY 2020}

(3) $S_{TOTAL,i} = S_{i-1} + S_i$ $\quad$ i= {EY 2014, EY 2015,…, EY 2020}

(4) $S_{TOTAL,i} \geq S_{TARGET,i}$ $\quad$ i= {EY 2014, EY 2015,…, EY 2020}

(5) $S_{TOTAL,2020} = S_{TARGET,2020}$

(6) $S_i \geq 0$ $\quad$ i= {EY 2014, EY 2015,…, EY 2020}

Again, this optimization problem is more or less the same as the profit maximization problem, specifically in terms of constraints and the decision variables. The main difference is that the objective seeks to minimize the net present value of the cost of producing SRECs in EY 2014-2020.

Chapter 5 Results of the Optimization Model

Profit Maximization

Once the model was properly configured with constraints, decision variables, and objective equations, the solver was exercised to find the optimal SREC issuances for EY 2014-2020. The following Table 5.1 is the culmination of the maximization effort. The column "New SRECs" and the "Net Discounted Profit" been bolded.

Table 5.1 The SREC Net Discounted Profit Optimization

Year	Incremental Target	New SRECs	Banked SRECs	Total SREC Supply	SREC Prices ($/MWh)	Revenues	Solar PV Cost ($/MWh)	Total Cost	Profit
2009	130,266	**77,910**	-	77,910	$446.78	$58,200,243	$275	$21,425,250	$36,774,993
2010	64,734	**130,161**	65,427	130,161	$566.28	$36,657,570	$270	$35,143,470	$1,514,100
2011	111,000	**285,415**	239,842	350,842	$607.47	$67,429,170	$250	$71,353,750	$3,924,580
2012	136,000	**713,271**	817,113	953,113	$343.85	$46,763,600	$250	$178,317,750	$131,554,150
2013	154,000	**1,082,009**	1,745,122	1,899,122	$213.13	$32,822,020	$240	$259,682,160	$226,860,140
2014	1,111,931	**99,231**	732,422	1,844,353	$339.00	$376,944,609	$230	$22,823,182	$354,121,427
2015	363,872	**7,728**	376,278	740,150	$211.53	$76,970,700	$210	$1,622,890	$75,347,809
2016	288,573	**720**	88,425	376,998	$201.08	$58,026,085	$200	$143,989	$57,882,096
2017	253,204	**164,779**	0	253,204	$315.00	$79,759,260	$180	$29,660,181	$50,099,079
2018	216,056	**216,056**	0	216,056	$308.00	$66,545,248	$160	$34,568,960	$31,976,288
2019	123,221	**123,221**	0	123,221	$300.00	$36,966,300	$140	$17,250,940	$19,715,360
2020	126,282	**126,282**	0	126,282	$293.00	$37,000,626	$120	$15,153,840	$21,846,786
								Net Discounted Profit	**$114,025,381**

The optimal discounted profit for the NJ SREC market, from the perspective of one entity installing one hundred percent of capacity in the state, was $114,025,381. The decision variable, SREC production in the state, yielded the following results once the solver had been exercised (the incremental target has been included for ease of comparison).

Table 5.2 Profit Maximizing SREC Issuance EY 2014-2020

Energy Year	SRECs To Be Issued	Incremental Target
2014	99,231	1,111,931
2015	7,728	363,872
2016	720	288,573
2017	164,779	253,204
2018	216,056	216,056
2019	123,221	123,221
2020	126,282	126,282

Due to the oversupply analyzed previously in Table 2.1, the market enters EY 2014 with a significant amount of SRECs in the bank. This means that SREC production does not necessarily have to surpass the incremental target for the foreseeable future, such as in EY 2014-2017. The function detailing the relationship between price and supply, coupled with the parameters of the solver, produced the following price forecast.

Table 5.3 SREC Price Forecast for Profit Optimization Model

Energy Year	SREC Price ($/MWh)
2014	$339.00
2015	$211.53
2016	$201.08
2017	$315.00
2018	$308.00
2019	$300.00
2020	$293.00

Cost Minimization

The results of the cost minimization problem are detailed in Table

Table 5.4 The SREC Net Discounted Cost Minimization

Year	Incremental Target	New SRECs	Banked SRECs	Total SREC Supply	SREC Prices ($/MWh)	Solar PV Cost ($/MWh)	Total Cost	Profit
2009	130,266	77,910	0	77,910	446.78	$275	$21,425,250	$36,774,993
2010	64,734	130,161	65,427	130,161	566.28	$270	$35,143,470	$1,514,100
2011	111,000	285,415	239,842	350,842	607.47	$250	$71,353,750	$3,924,580
2012	136,000	713,271	817,113	953,113	343.85	$250	$178,317,750	$131,554,150
2013	154,000	1,082,009	1,745,122	1,899,122	213.13	$240	$259,682,160	$226,860,140
2014	1,111,931	-	633,191	1,745,122	200.00	$230	$0	$222,386,200
2015	363,872	-	269,319	633,191	200.00	$210	$0	$72,774,400
2016	288,573	19,254	0	288,573	228.51	$200	$3,850,800	$62,091,098
2017	253,204	253,204	0	253,204	315.00	$180	$45,576,720	$34,182,540
2018	216,056	216,056	0	216,056	308.00	$160	$34,568,960	$31,976,288
2019	123,221	123,221	0	123,221	300.00	$140	$17,250,940	$19,715,360
2020	126,282	126,282	0	126,282	293.00	$120	$15,153,840	$21,846,786
						Net Discounted Cost	$430,494,496.74	

The minimal net discounted cost to consumers of the SREC program was optimized at $430,494,496.74. It should be noted that reducing the net discounted cost to this value caused net discounted profit for producers to fall to $33,557,077.99. This value is over $80 million less than the optimal net discounted profit as calculated in the maximization problem.

Table 5.5 details the SREC issuance schedule that would minimize cost to the consumer for EY 2014-2020.

Table 5.5 Cost Minimizing SREC Issuance EY 2014-2020

Energy Year	SRECs To Be Issued	Incremental Target
2014	-	1,111,931
2015	-	363,872
2016	19,254	288,573
2017	253,204	253,204
2018	216,056	216,056
2019	123,221	123,221
2020	126,282	126,282

This SREC production rate resulted in the following forecast for SREC prices in EY 2014-2020.

Table 5.6 SREC Price Forecast for Cost Minimization Model

Energy Year	SREC Price ($/MWh)
2014	200.00
2015	200.00
2016	228.51
2017	315.00
2018	308.00
2019	300.00
2020	293.00

It should be noted that for many of the future energy years within the model, the price operates at the SACP. This suggests that in order to optimize the market from a producer profit standpoint, one should produce less in order drive price towards the SACP. The spike in RPS requirement, which goes into effect in EY 2014, will help to assuage the oversupply problem, and potentially increase prices. The market has been observing prices at extremely low levels. This model reflects the concept that if solar production were slowed down simultaneously with this increase, prices have the potential to recover. For example, EY 2013 saw over 1,000,000 SRECs issued, and yet the model suggests an issuance of less than 100,000 in 2014. With the price-supply regression function, it was calculated that a decrease in production could push prices to levels at or near the SACP, which would work towards maximizing the value of the SREC program.

The cost minimization problem suggests an even more radical approach, as the SREC issuance rate that minimizes net discounted cost to the consumer involves having no solar production in EY 2014 and 2015. It is suggested that in general, one should put off producing more SRECs as long as possible so that their cost is discounted further into the future.

Conclusions

Reducing or cutting off SREC production completely is more easily said than done, however, as it is not anticipated by the NJ BPU, SEIA, or any other organization that NJ solar production will decrease in the coming energy years. The optimization model uses the assumption that one entity is in charge of all solar installation in the state of New Jersey. This assumption was made in order to answer the question, if one person was trying to find the optimal SREC issuance rate in terms of profit or cost, what would they do given the ability to control the whole market? The NJ solar industry has many participants in reality and while the model can tell us the best SREC issuance rate overall, observing that issuance rate is unlikely to occur. It is very difficult to seek out any implementation of an optimal SREC issuance rate in terms of maximum profit or minimum cost. The SREC Program is an effective form of incentive from the standpoint that it promotes solar investment, however those who enter the market will continue to see the effects of oversupply for many energy years to come.

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Academic Vita

Connor Brady
328 West Nittany Avenue
State College, PA 16801
cxb5106@psu.edu

Education

The Pennsylvania State University, University Park
The College of Earth and Mineral Sciences
- Major: B.S. Energy Business and Finance

Experience

Allied Building Products, Solar Division, Inside Sales Representative
- Assisted in increasing sales by roughly 100% from July to August 2013
- Implemented and managed new web marketing campaign, increasing market penetration
- Maintained close relationship with new and existing customers, completed sales

Beach Electrical Contracting, Inc, Intern
- Accepted and delegated subcontracting bid invitations to project managers
- Accounted for fixture quantities and pricing to ensure accurate project valuation
- Communicated effectively with General Contractors and Project Managers

Pennsylvania State University, Sustainability Council Communication Intern
- Founded and managed council website and Facebook page
- Disseminated "green" information and initiatives to campus population

Leadership

Phi Beta Lambda Co-Ed Business Fraternity
Executive Board Member
- Elected to serve as an Executive Board Member in an advisory capacity to fraternity president
- Organize and execute fundraising, professional, social, and philanthropic events including THON
- Conduct interviews for over 50 potential new members per semester

Event Coordinator
- Plan and organize fraternity social events for brothers and alumni
- Oversee fraternity IM Sports Program and manage budget
- Assist in fraternity related events to help maintain a brotherhood of 94 men and women

Penn State Global Environmental Brigades
- Completed reforestation and permaculture project in rural Panama
- Organized fundraising events to reach $20,000 fundraising goal

The Penn State IFC/PanHellenic Dance Marathon
- Participated in yearlong fundraising effort to combat pediatric cancer
- Elected to represent Phi Beta Lambda as an official dancer to stand for 46 hours from Feb. 21-23, 2014
- Organized and executed independent fundraising efforts to benefit THON

Awards/Recognition

- **Gerard L. Bayles Memorial Scholarship**
- **Phi Sigma Delta Sigma Educational Foundation Scholarship**