Energy Policy 44 (2012) 217–225

Contents lists available at SciVerse ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Comparative economic analysis of supporting policies for residential solar PV in the United States: Solar Renewable Energy Credit (SREC) potential

John Edward Burns, Jin-Su Kang *

Institute of Business and Management, National Chiao Tung University, Taiwan, ROC

ARTICLE INFO

Article history:
Received 19 August 2011
Accepted 23 January 2012
Available online 10 February 2012

Keywords:
US
Solar Renewable Energy Credit
Residential solar PV

ABSTRACT

Numerous studies and market reports suggest that the solar photovoltaic markets rely heavily, if not entirely, upon governmental support policies at present. Unlike in other countries where these policies are enacted at a national level, the 50 states in the US pursue different policies in an attempt to foster the growth of renewable energy, and specifically solar photovoltaics. This paper provides an economic and financial analysis of the US federal and state level policies in states with solar-targeted policies that have Solar Renewable Energy Credits (SREC) markets. After putting a value on SRECs, this study further compares solar carve-outs with other incentives including the federal tax credit, net metering, and state personal tax credits. Our findings show that SREC markets can certainly be strong, with New Jersey, Delaware, and Massachusetts having the most potential. Despite their strong potential as effective renewable policies, the lack of a guaranteed minimum and the uncertainty attached are major drawbacks of SREC markets. However, the leveraging of this high value offers hope that the policies will indeed stimulate residential solar photovoltaic markets.

1. Introduction

Among many factors driving global *Solar Photovoltaic* (SPV) demand, this study focuses on government policy, specifically focusing on financial incentive policies implemented in support of SPV. SPV is a high cost renewable resource, and therefore has lagged behind other sources of renewable energy, so subsidies and incentives are considered among the key drivers of global SPV demand (Wiser et al., 2010).

The US energy market is different from other nations in that energy is primarily regulated at a state level or lower rather than on a fully national scale. Likewise, electrical energy companies in the US operate at a state or regional level, not typically on a fully national scale. Consequently, each state functions effectively as a separate energy market, and thus each state is thereby a separate SPV market. Given the web of different incentives each state provides, it is difficult to quantify how much each different policy affects the SPV industry.

Many states have been passing renewable energy support policies over the past decade, with the most common method being a *Renewable Portfolio Standards* (RPS) (Wiser et al., 2010). Additionally, states specifically target SPV by creating solar *set-asides* or *carve-outs* within the RPS specifically requiring a percentage of energy to be derived from SPV. One of the most common ways to enforce set-asides is through Solar Renewable Energy Certificates or *Solar Renewable Energy Credits* (SREC) markets, nine of which are in place as of July 2011 (DSIRE).

SREC markets are fresh in the US, and subsequently very few studies have evaluated them in depth. Previous studies explore the value of financial incentives in the US SPV market, but intentionally leave out valuing SRECs due to their speculative nature (Barbose et al., 2011; Wiser et al., 2010). This study attempts to place a quantifiable value on SRECs, and thus paint a better picture of the US SPV financial incentive landscape.

There have been many attempts to measure the success of government policies on renewable energy sources (Buckman, 2011; Menz and Vachon, 2006; Yin and Powers, 2010). One examination performs a comparative financial and economic analysis of each individual European nations' package of financial incentives for residential photovoltaics, estimating *Net Present Value* (NPV), *Discounted Cash Flows* (DCF), and *Internal Rate of Return* (IRR) of policies (Dusonchet and Telaretti, 2010a, b).

A comprehensive study of incentives in the US uses the *Present Value per Watt-Capacity* (Present Value/W_p), providing a metric to measure and compare the different incentives (Barbose et al., 2011). The analysis mentions the value of SREC policies, but does not go in great detail about SRECs, as they are considered too difficult to measure.

Thus, this study intends to provide insight into the newer SREC markets that populate US RPS policies. Through financial analysis using NPV, DCF, IRR, and Present Value/W_p, we intend to answer the following questions:

1. Which of the US states with solar carve-outs that include SREC policies have the most robust overall state-level package of incentives for residential SPV?

* Corresponding author.
E-mail addresses: jskang@mail.nctu.edu.tw, jinsu.kang@gmail.com (J.-S. Kang).

0301-4215/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
doi:10.1016/j.enpol.2012.01.045

2. What is the value of SREC markets to residential SPV, and which SREC markets are strong enough to be as effective as other financial incentives: *Net Metering*, or personal tax credits?

The remainder of the paper is organized as follows. In Section 2, we present a succinct overview of the many different financial incentive policies in the US at the state and federal level. Then, a comprehensive overview of SREC markets follows, providing a state-by-state breakdown of US SREC markets in place as of October 2011. We apply conventional financial metrics, including Present Value, NPV, DCF, and IRR, to compare states' financial incentives. Then, Present Value per W_p compares SREC value versus the other policies. Section 5 presents the findings, and Section 6 is a conclusion.

2. Supporting policies in the United States

At the federal level, a personal income tax credit is provided, while state and municipal authorities employ various SPV-targeted tax incentives in the form of tax exemptions, tax deductions, and tax credits.

While Feed-in-Tariffs (FIT) have been prevalent and successful at stimulating SPV in Europe (Dusonchet and Telaretti, 2010a; Lipp, 2007), the 1978 Public Utilities Regulatory Policies Act (PURPA) has made it difficult to establish European-style FITs in the US (Hempling et al., 2010). As such, FITs are not prevalent in the US, and states tend to pass other forms of incentive policies to stimulate residential SPV.

Most of the different policies are separate laws, and as such represent different incentives that can be cumulated on top of each other (DSIRE), and the resulting package of incentives can be used to offset the higher price of energy from SPV. However, each state is different in their method of supporting SPV, and not all policies can be cumulated. Those which cannot be cumulated are explained and accounted for when performing the financial evaluation. The following sections introduce the financial incentive policies in place in the US related to SPV market examined through financial analysis within this study.

2.1. Tax credits

The federal "Residential Renewable Energy Tax Credit" is a non-refundable personal tax credit and applies only to residential renewable energy systems. As this is a federal incentive, there are no differences among the states. Many states have also passed personal income tax credits, although in this study the only two that have them are Massachusetts and North Carolina.

The federal government allows SPV installations a one-time credit equivalent to 30% of the cost of installation. The price of the installation includes equipment, on-site preparation, assembly or original installation, labor costs, wiring, and piping for connection with the grid (US Department of Energy). The tax credit was established on January 1, 2006, and is scheduled to expire on December 31, 2016 after recently being extended past 2011. It is not guaranteed, and must be approved when filing income taxes.

2.2. Cash rebates

Many states pass financial incentives in the form of *cash rebates*, which are a dollar amount paid per watt-capacity of SPV energy installed. These incentives have been shown effective at reducing installed SPV costs (Wiser et al., 2010; Barbose et al., 2011). However, cash rebates often suffer from a lack of funding, and are paid out on a first-come first-serve basis until the budget dries up, and as such are not guaranteed, as happened in Pennsylvania as of August 2011 (DSIRE). So, while studies of funding for installed projects that received rebates is possible, for the purposes of this study, rebates are not considered.

2.3. Net Metering

The simplest incentive for renewables is Net Metering. This allows customers to offset their electricity use by the amount of energy their integrated renewable systems generate. Each state's law has different wording and different specifics on how they go about employing Net Metering laws.

Integrated SPV systems are required to have a specified meter that records the flow of electricity in both directions. Each month the meter records the inflow of electricity from utility providers, and also records the outflow of electricity generated by the residence and pumped back into the electricity grid. All the energy produced and consumed locally by an SPV system is effectively a savings equal to the retail electricity price at the time they produced and consumed their electricity.

Should the system generate electricity in excess of consumption each month, this *Net Excess Generation* (NEG) can be carried forward as credit against future energy consumption in the coming months, or paid out to the residence – normally at year's end (DSIRE). The price paid for this excess generation is different in each state. Most states allow SPV generators to receive the retail price for the excess generation; others allocate NEG differently (DSIRE). Should a customer's year-end energy bill have excess generation over the customer's annual residential consumption, the customer is then entitled a cash rebate equivalent to NEG from the utilities company (DSIRE).

In essence, Net Metering is designed to allow customers to profit off the total amount of energy they generate – not just the amount of energy they consume locally from their SPV system. Unfortunately, the cost of energy from SPV is above the market price, thus net metering alone is not necessarily enough to put SPV in competition with traditional means of electric energy production.

Table 1 shows the summary of Net Metering for nine states related to this study: How the state handles NEG and the maximum capacity for a Net Metering system. Additionally, the 2010 Average Retail Energy price per kW h, and the 20-year nominal annual change in energy price is provided to give a comprehensive view of Net Metering policies within each state.

2.4. Renewable portfolio standard (RPS)

Each state has strong, but not complete authority to regulate the utilities companies serving their residents. As such, many states have been setting goals and requirements for electrical energy production from renewable resources similar to those seen in Europe. As of March 2011, 33 states and the District of Columbia have RPS programs in place (US Environmental Protection Agency).

These different RPS strategies cover the whole spectrum of renewable energy, and implementation varies by state. States require utilities companies to acquire a *Renewable Energy Certificate* (REC) which is equivalent to 1 MW h of energy created by a renewable resource, similar to Tradable Green Certificates (TGC) found in some European nations.

Should an insufficient amount of RECs be produced or purchased by energy producers, energy producers pay an *Alternative Compliance Payment* (ACP). The ACP for each RPS is different and subject to adjustment. Ohio's is \$45 per MW h, New Jersey's is \$50 per MW h; Ohio's ACP decreases \$5 per MW h bi-annually, whereas New Jersey's has remained unchanged since 2004.

Table 1
State energy overview and Net Metering policy.

State	Max capacity[a]	NEG allocation[a]	Change in energy price per kW h[b]	2010 avg. energy price per kW h[c]
District of Columbia (DC)	–1 MW	Retail rate	$0.002807	$0.1401
Delaware (DE)	25 kW	Retail rate	$0.002199	$0.1380
Massachusetts(MA)	60 kW	Retail rate	$0.003301	$0.1459
Maryland (MD)	1 MW	Retail rate	$0.002329	$0.1432
North Carolina (NC)	1 MW	Retail rate	$0.000830	$0.1012
New Hampshire (NH)	1 MW	Avoided cost rate[d]	$0.001950	$0.1632
New Jersey (NJ)	No limit	Credited at retail rate; reconciled annually at avoided rate[d]	$0.001778	$0.1657
Ohio (OH)	No limit	Unbundled generation rate[e]	$0.000178	$0.1132
Pennsylvania (PA)	50 kW	Retail price	$0.000735	$0.1270

[a] DSIRE portal.
[b] 20-year average annual nominal change in energy price per kW h (US Energy Information Agency).
[c] US Energy Information Agency, 2010 average retail energy.
[d] Avoided cost is the cost that a utilities company would have to pay to produce the energy itself, or the marginal cost of generating an additional unit of electricity for the utilities company (Hempling et al., 2010).
[e] Energy prices tend to be *bundled* to include the cost of generation, transmission costs, distribution costs (DTE Energy). In Ohio, annual NEG reconciliation is done at the generation rate only (DSIRE).

Unfortunately, due to the higher cost of SPV, the basic RPS goals have proven ineffective at stimulating SPV development (Wiser et al., 2010). As a result, states have been modifying their RPS systems by adding technology-specific set-asides.

2.5. Solar set-asides

The term “set-aside” or “carve-out” refers to a provision within an RPS that requires utilities companies to use a specific renewable source (usually photovoltaic energy) to account for a certain percentage of their retail electricity sales (or a certain amount of generating capacity) according to a set schedule. As of March 2011, the US had 16 states with solar set-asides or distributed generation (US Department of Energy). These set-asides are required percentages of state energy production from SPV. For example, Ohio’s RPS has a 2025 target of 12.5% renewable energy production, and 0.5% from solar as per its solar set-aside terms.

2.6. Solar Renewable Energy Credits (SRECs)

Among the different US states, this type of policy has picked up steam, and several states have enacted these solar credit markets; tradable SREC markets exist in nine states (US Department of Energy). An SREC is created for every 1 MW h of solar energy produced in a given energy year. It makes no difference if the MW h is auto-consumed locally by a residential SPV system or sold back into the grid; every MW h produced from SPV produces an SREC.

As per the solar carve-out, these SRECs fall under different regulations. Specifically, the associated ACP is also a special *Solar Alternative Compliance Payment* (SACP), and these SACPs are usually significantly higher than the standard ACP – often 10 times the ACP price. Many SACPs have a set timetable whereby the price of SACP decreases annually, while others do not. At the same time, the quantity of SRECs mandated to be purchased increases annually as the solar carve-out percentage increases. The way utilities companies acquire SRECs is up to them. They are allowed to build solar production, purchase SRECs from private SPV energy producers, or pay the SACP.

Due to the nature of SRECs, the SACP acts as a cap on the price of an SREC, because a utilities company has no need to buy an SREC at the same price as it does to pay the SACP. No scenario exists where an SREC should exceed the SACP in price. Accordingly, SREC prices per state tend to stay very close to the SACP as long as the market is not oversupplied.

SPV systems are not eligible for SREC creation by default; they must be set up to meet all the safety and technical requirements and certified by their state utilities authority. Additionally, each state’s SREC law sets a date (usually 1 year before the SREC market creation) that SPV systems must be newer than to be eligible (DSIRE). This study is on the establishment of new residential SPV systems, and the associated financial analysis, so only new SPV systems are investigated.

To create SRECs, an SPV system owner must set up an approved tracking system that monitors the kW h produced, and creates an SREC for each MW h of SPV produced electric energy. This is surprisingly simple for the grid management companies to arrange. The electric grid is not run directly by electric energy producers, but instead private companies operate across various regions, working with multiple utilities companies. The largest grid infrastructure company is PJM in the east where most of the SREC markets exist. PJM’s General Attribute Tracking System (GATS) monitors electric energy generation, and stores each MW h produced by a system with a unique serial number (PJM, 2011). Compared with other Green Credit markets that can take over 2 years for a similar process (Dusonchet and Telaretti, 2010a), SREC registration is relatively quick, and usually takes about 2 months to complete (PJM, 2011). These SRECs are then tradable, and can be held and sold at any point within the *SREC Life*. Each SREC policy sets a different expiration date for SRECs to be retired by utilities companies, ranging from 1 year to 5 years, and should an SREC go unused past its expiration date, it is worthless.

3. SREC state policies

In this section, only those American states with RPS solar carve-outs that contain SREC policies are evaluated. An in-depth overview of the state policies is provided for each of the eight states where SREC markets are in place as of May 2011 (Table 2).

3.1. District of Columbia (DC)

DC passed its RPS in 2005, and amended it in 2008 increasing the requirements and ACPs. The solar target began at 0.005% in 2007, scaling up to 2.50% by 2023 (DSIRE). The SACP is a fixed

Table 2
Overview of SREC by state.

State	2010 SACP[a]	SREC life[a]	Carve-out target[a]	SREC policy initiated[b]	2010 SPV price per Watt[c]	Avg. solar output (kW h/kW$_p$)[d]	System eligibility[a]
DC	$500.00[e]	3 years	2.50% by 2023	2007	$7.51	1240	No limit
DE	$400.00[f]	3 years	3.5% by 2026	2008	$7.30	1240	No limit
MA	$600.00[g]	1 year	400 MW$_p$ by 2020	2010	$6.91	1232	No limit
MD	$400.00[h]	3 years	2.00% by 2023	2008	$6.54	1228	No limit
NC	–[i]	2 years	0.2% by 2018	2010	$7.31	1310	Unspecified
NH	$160.01	2 years	0.3% by 2014	2010	$6.25	1236	No limit
NJ	$693.10[j]	3 years	5316 GW h by 2026	2004	$6.78	1216	15 years
OH	$400[k]	5 years	0.5% by 2024	2009	$6.20	1176	No limit
PA	$654.37[l]	3 years	0.5% by 2021	2009	$6.85	1145	No limit

[a] DSIRE portal.
[b] Wiser et al., 2010.
[c] NREL Open PV project: Avg. price for projects 1–10 kW$_p$.
[d] NREL: PVWATTS.
[e] $500 through 2016, declining $50 by 2023.
[f] $400 indefinitely, increases $50 each time SACP is used.
[g] $550 in 2011, but no set timetable.
[h] $400 until 2014, decreasing to $50 by 2023.
[i] No SACP has been set.
[j] Declines 2.5% annually at least for next eight years.
[k] Declines $50 bi-annually to a minimum of $50 in 2024.
[l] SACP changes annually based on the market price of SREC in the previous energy year.

amount of $500 through 2016, declining to $350 for 2017, $300 in 2018, $200 in 2019 and 2020, $150 in 2021 and 2022 and $50 in 2023 and thereafter.

DC allows solar credits produced outside of DC in states as far as Wisconsin to be purchased and retired by DC utilities companies in order to meet their RPS requirements. Out of state generated MW h can be used as SRECs in DC only if the resources within DC are "exhausted" (US Department of Energy). DC SPV systems have no set limit on how long they can produce SRECs, and the SREC policy is set to last through 2023 with an indefinite future thereafter. This study assumes the 2023 year to be the final year of DC's SREC policy, and calculates SREC potential only to the firm 2023 date and not beyond.

3.2. Delaware (DE)

Delaware established its RPS originally in 2005 with a 10% goal by 2020, but was then modified to be 20% by 2026 with a 2.005% solar carve-out in 2007. Later it was scaled up again to 25% and 3.5%, respectively. Delaware SPV systems have no set time limit on how long they can produce SRECs, although the current SREC policy goal of 2026 marks an unofficial date after which SREC policy may no longer be enforced.

Delaware's SACP system is particularly unique because there is a punishment attached. Each time a company uses an SACP instead of submitting an SREC, the next year it must pay an additional $50 for each SACP again. If a Delaware energy producer meets its compliance by acquiring 70% SRECs, and paying 30% SACPs of $400 each, the next year the number of SACPs purchased at $400 go up to $450, and any subsequent SACPs are paid at the lower $400 price. This scales up indefinitely at $50 each year with no maximum.

3.3. Massachusetts (MA)

The Department of Energy Resources (DOER) has created a sufficiently complex RPS, with a total goal of 15% by December 31, 2020. It is tiered with 15% into Class 1 resources (of which SPV is included). In 2010, DOER created a unique solar carve-out of 0.0679% the total energy produced each year until 400 MW$_p$ SPV is installed within MA. After 400 MW$_p$ is reached, SPV falls back under the Class 1 status, and would have a lower ACP (DSIRE). An SPV system must be under 6 MW$_p$ in capacity to qualify for SREC production (effectively eliminating Concentrated Solar Plants). There is no specified term limits on how long an SPV system can be eligible for SREC production. However, the nominal 400 MW$_p$ goal and 2020 deadline serve as an effective limit. Therefore, this study assumes that MA SPV systems do not gain monetary value from SRECs after 2020.

In Massachusetts the SACP is $600 in 2010, decreases to $550 in 2010 with no set increase or decrease thereafter. They guarantee no annual reduction in SACP greater than 10% in a given year to alleviate price uncertainty. Additionally, DOER has created a Solar Credit Clearinghouse Auction through which SREC holders can sell their SRECs. This auction has a minimum SREC cost of $300, effectively creating a floor of $300 and a ceiling of $550 for the price of any SREC.

Massachusetts also has had a personal income tax credit for residential SPV systems since 1979. This tax credit is set at 15% of the cost of installation for the SPV system up to a maximum of $1000 (M.G.L. Ch. 62. Section 6(d)). The credit can be carried forward for a maximum of 3 years should the amount be greater than the owner's tax burden. There is no specification on whether the taxable amount can be cumulated upon other tax credits, however the federal tax credit does specify that it is applicable less all other credits, etc. (US Department of Energy; Federal Tax Credits for Energy Efficiency) Therefore, for purpose of this study, the federal tax credit amount applied to Massachusetts is taken from the amount less the MA tax credit.

3.4. Maryland (MD)

Maryland enacted its RPS in 2004, and subsequently revised it several times to include a solar carve-out, and tiers targeting a wide range of renewables. The solar carve-out is aggressive, and scales up from 0.005% in 2008 to 2% in 2022. Maryland's SACP is set at $400, and was set to decline according to a timetable, but in December 2010 Maryland approved extending the $400 SACP through 2016 to increase the strength of the program. After meeting the 2022 requirement of 2%, the SACP is set to drop to $50 in 2023 and remain indefinitely thereafter.

Maryland's solar set-aside requires the owner of a system that generates an SREC to first offer the SREC to a utilities electricity producer for RPS compliance. It is not specified, but the law requires the SREC producer to post the SREC for sale on Maryland's Public Service Commission (PSC)'s website for a minimum of 10 days before the SREC holder is allowed to sell their SREC to another person or entity (Maryland Public Service Commission).

Additionally, should the electricity suppliers decide to purchase their SREC directly from the SREC producer, the solar energy system owner must enter into a contract for at least 15 years. Specifically, for SPV systems under 10 kW in capacity (residential), the purchaser must pay the value of the contract in a "single, up-front payment arrived at by calculating the Net Present Value of SRECs over the life of the contract using a standard SREC value of 80% of the SACP and federal secondary credit interest rate in effect as of January 1 of that year as the discount rate" (DSIRE). As residential SPV systems produce a small number of SRECs annually, the real-life effect is that utilities do not purchase directly from residences often preferring to buy from aggregators or pay the SACP (US Photovoltaics, 2010).

3.5. North Carolina (NC)

North Carolina is still in the early stages of implementing their SREC program. North Carolina's RPS has a solar carve-out of 0.2% by 2018, but since its passage in 2010 and scheduled beginning, the North Carolina market has not materialized as of yet. The law does not require the North Carolina Utilities Commission (NCUC) to set an associated SACP (DSIRE). Additionally, the low 0.2% requirement, and the rapid decrease in utility-scale SPV costs in North Carolina have allowed NC utilities providers (Duke being the largest) to meet their compliance requirements with their own resources rather than resort to buying SRECs from other sources (Urlaub, 2011).

Additionally, North Carolina's Net Metering laws are unique in that customers choose a rate schedule for pricing the electricity they generate from their SPV systems. They can choose to take a favorable rate schedule, but at the penalty of signing over their SRECs to the utilities company in return. However, SPV owners are allowed to keep their SRECs should they choose a less favorable demand tariff (DSIRE). Therefore, by NC's law, an SPV user basically is faced with a choice of picking NM or SRECs as a financial incentive.

North Carolina also has a personal tax credit of 35% all installation costs less rebates, or other public fund assistance, although in 2010 a revision clarified that funds received per the American Recovery and Reinvestment Act of 2009 do not constitute public funds (Senate Bill 388). The tax credit for SPV has a maximum of $10,500 and cannot exceed 50% the year's tax liability less all other tax credits (DSIRE). This tax credit must be taken and used against the tax burden in the year the SPV system is installed, although should the amount exceed the tax burden the remaining amount may be carried forward and used for a maximum of 5 years (DSIRE). However, the low carve-out requirement, lack of an SACP, and NM policy make it so calculating the SREC value infeasible.

3.6. New Hampshire (NH)

New Hampshire passed its RPS in 2007 with a goal of 23.5% renewable energy generation by 2023. This RPS includes a solar carve-out provision targeting 0.3% by 2014, with an SREC market to be formed for 2010. The associated Alternative Compliance Payment for the solar carve-out was $160.01 in 2010, and is subject to review annually to be increased based on the Consumer Price Index (DSIRE). The 2011 SACP was increased to $163.16 based on the CPI figures. Any new SPV system that started generating power after January 1, 2006 is eligible to generate SRECs (DSIRE).

3.7. New Jersey (NJ)

New Jersey's solar market ranks second only to California. New Jersey originally passed their RPS system in 1999 under a different name, and subsequently added in separate requirements for "Class 1" and "Class 2" energies (SPV is a Class 1). Then in 2006, NJ added a specific solar carve-out. NJ has a target of 22.5% renewable energy production by 2021, and a solar carve-out of 2.12%. This goal has since been revised to 5316 GW h of solar generation by 2025–2026.

There is a set timetable for SACP reduction, at $693 in 2009–2010 set to decrease by 2.5% annually until 2016, and the New Jersey The citation "NJ Board of Public Utilities" has been changed to "New Jersey Board of Public Utilities" to match the author name/date in the reference list. Please check and correct if necessary.The citation "NJ Board of Public Utilities" has been changed to "New Jersey Board of Public Utilities" to match the author name/date in the reference list. Please check and correct if necessary.Board of Public Utilities has provisionally said it will continue this strategy through 2019. NJ SRECs currently have a life of 3 years after the MW h is produced, having been revised up from 1 year in 2009.

Solar facilities are allowed to accrue SRECs per kW h produced over its "15 year qualification life" (DSIRE). This means a solar facility is only eligible to produce SRECs for 15 years after being connected to the grid, and can be sold any point within 3 years after their creation.

3.8. Ohio (OH)

Ohio passed its SREC policy started in 2009 with an initial 0.004% requirement set to increase to s 0.5% solar retail energy production by 2024 and beyond. Ohio's SRECs have a 5-year life during which they can be used by utilities companies to count against their SACP requirements. The SACP in Ohio has a set time-table decreasing $50 bi-annually until 2024 where a $50 SACP is set to be permanent. Registered SPV systems can generate SRECs indefinitely, and the SREC policy is set to last through 2024 and beyond subject to review by Public Utilities Commission of Ohio (PUCO).

3.9. Pennsylvania (PA)

Pennsylvania titled its RPS "Alternative Energy Portfolio Standard (AEPS)," and its SREC is called a "Solar Alternative Energy Credit (SAEC)." However, they act the same as other SREC programs. Pennsylvania has a tiered system of requirements totaling 18% renewables by 2021 with a 0.5% solar set-aside up from 0.0120% in 2010.

The SACP is calculated every year by the Pennsylvania Utilities Commission (PUC), and is based on the weighted average price for an SAEC within Pennsylvania during the previous year. In 2008, the SACP was $528.17, $550.15 in 2009, and in 2010 it was $654.37 (DSIRE). Despite a 2009–2010 SACP of $654.37, the average SAEC for that year was $325. Due to Pennsylvania's undetermined future SAEC price, it is also not possible to calculate its SREC market, so the subsequent financial analysis does not include Pennsylvania.

4. Comparative economic analysis framework

4.1. Theoretical framework

Comparative economic analysis is performed by calculating the cash flows, NPV, and IRR for each state's package of policies. Then a present value for the cash flow from each separate individual policy is calculated to compare the potential for the SRECs against the other policies that make up the state incentive package. This study examines seven of the nine states with SRECs, leaving out Pennsylvania and North Carolina as it is not possible to value their SREC policies due to their SACP pricing regulations.

Cash flows depend on many factors (average state energy price, solar radiation, SPV price, etc.), and various policies from the assortment of federal and state-level incentives (SREC income, net metering income, and tax credits). The cash flows for each state are calculated the same as has been done in previous studies (Dusonchet and Telaretti, 2010a, b; Barbose et al., 2011). The cash flows are taken as the sum of all the costs and profits in any year t using the following:

$$C_t^* = F*E_t + c_{\mathrm{kW\,h},t}*E_t + C_0*T_{\mathrm{fed}} + C_0*T_{\mathrm{state}} - u*C_0 - C_{\mathrm{add}} \quad (1)$$

where: ***F* is the SREC value in year *t***; E_t is the energy produced in kW h in year t; $c_{\mathrm{kW\,h},t}$ is the energy price per kW h in year t; C_0 is the up-front cost of installation; T_{fed} is the Federal tax credit (as a percentage of initial cost); T_{state} is the state tax credit (as a percentage of initial cost); u is the maintenance fee, estimated as a percentage of initial cost; C_{add} is the insurance cost for the system over its lifespan.

Then, these cash flows are discounted using the classical expression for discounted cash flows to get the present value of each year (to be summed later) as has been done in prior research (Dusonchet and Telaretti 2010a, b):

$$C_t = \frac{C_t^*}{(1+i)^t} \quad (2)$$

where i is the discount factor or cost of capital. Then the classic methods for calculating NPV and IRR are applied as follows:

$$NPV = \sum_{t=1}^{N} \frac{C_t^*}{(1+i)^t} - C_0 \quad (3)$$

$$\sum_{t=1}^{N} \frac{C_t^*}{(1+IRR)^t} - C_0 = 0 \quad (4)$$

where N is the lifetime of the investment.

The *present value for each of the different portions* of cash flows (as calculated in Eq. (1), and discounted in Eq. (2)) is calculated. This helps give a clearer view of exactly which of the various policies have the largest impact on the NPV, and to compare each different policy separately. Finally, *each separate these present values is divided by the capacity of the system* to get an accurate view of just how much value a residential SPV owner receives per W_p installed from each separate financial incentive.

SREC per W_p:

$$\frac{\sum_{t=1}^{15}((F*E_t)/(1+i)^t)}{W_p} \quad (5)$$

Net Metering Present Value per W_p:

$$\frac{\sum_{t=1}^{15}((c_{\mathrm{kW\,h},t}*E_t)/(1+i)^t)}{W_p} \quad (6)$$

Federal Tax Present Value per W_p:

$$\frac{((C_0*T_{\mathrm{fed}})/(1+i))}{W_p} \quad (7)$$

State Tax Present Value per W_p:

$$\frac{((C_0*T_{\mathrm{state}})/(1+i))}{W_p} \quad (8)$$

4.2. Operational assumptions

Residential SPV systems range between 2 kW_p and 10 kW_p, so the comparative analysis refers to a 4 kW_p built-in residential SPV system. Some studies use a 10 kW_p system, but that is larger than the average residential SPV. The following assumptions are taken when performing this analysis, in accordance with what has been used in previous journal studies:

- Different policies are enacted in different states, but this focuses on the effects of solar targeted set-asides.
  - Rebates are ignored, as they are paid on a first come, first serve basis, and tend to have lower caps; other studies have covered these in-depth (Barbose et al., 2011).
  - Grants, loans, and capital subsidies are also cast aside for the same reason.
- Net metering calculations are based on the 2010 annual average residential electric energy price for each state (US Energy Information Administration) calculated for nine states of this study.
- State and Federal Tax credits are factored in, but discounted at the end of year 1.
  - In the case of a state tax credit, the state credit is first calculated based on the full taxable installation cost, and then the federal credit is taken from the installation cost less the state tax credit (Barbose et al., 2011).
- Solar Renewable Energy Certificate markets are factored in at a percentage of the SACP annually of 80%.
  - Due to the lack of firm SACP prices, Pennsylvania and North Carolina's policies are not evaluated.
- The most popular discount rates for SPV are 1%, 3%, 5%, and 7% with the lower interest rates seen as most appropriate for evaluating public policies (Borenstein, 2008). Thus, 3% is used in this study as was done in the European studies (Dusonchet and Telaretti, 2010a, b).
- The mean operative efficiency of the SPV system is calculated based on the National Renewable Energy Laboratory program PV Watts (National Renewable Energy Laboratory), whereby solar insolation for each point in the USA is calculated and used to determine operative efficiency for any point on Earth.
  - The base stations in each state are averaged to form a state average level of annual solar output per 1 kW_p of SPV.
  - The default PV Watts rates for energy loss and positioning are used (National Renewable Energy Laboratory).
- The average residential electricity price is based on the 2010 price for each state (US Energy Information Administration).
- The annual energy price increase is based on a 20-year average nominal increase for each state in the US during 1999–2009 (US Energy Information Agency).
- The total costs of the SPV system vary by state, and are based on the 2010 price per Watt for SPV systems 1–10 kW_p, as calculated from the National Renewable Energy Laboratory's Open PV Project.
- SPV annual maintenance costs are not uniform; the annual maintenance price is between 0.5% and 2.4% of the price of the installed plant cost (Koner et al., 2000). Lewis and Larry (2010) suggest a 0.12% of the initial capital expenditure as the annual operation and maintenance costs for SPV systems in the US. This study assumes 0.5% maintenance price as other studies have used (Denholm et al., 2009; Dusonchet and Telaretti, 2010a, b).
- The annual insurance cost for an US SPV system is between 0.25% and 0.5% of initial capital costs (Denholm et al., 2009). This study assumes an annual insurance cost of 0.5% of the initial capital cost.
- The SPV system is assumed to lose 0.5% efficiency annually (Denholm et al., 2009).

5. Results and discussion

5.1. Break-Even analysis

Table 3 shows the NPV and IRR for each of the states. The carve-outs show that New Jersey and Massachusetts followed by

Delaware are clearly out in front. Within only 15 years, residential SPV systems are profitable, and the internal rates of return are higher than the 3% discount factor. This is without even factoring in other incentives, like rebates.

The other states (DC, MD, NH, and OH) all have negative NPVs within 15 years, though they come close to break-even within that timeframe. Should the analysis continue out to 20 or 25 years as other studies have done (Denholm et al., 2009; Dusonchet and Telaretti, 2010a, b), then they would also break even or become net positive investments. Fig. 1 shows the cumulative discounted cash flow for each state.

5.2. Individual incentive potency: SREC potential vs. other policies

The SREC potential is evident simply in looking at the SACPs, and the present value analysis reflects such as the higher SACPs result in higher present value per W_p. Table 4 shows the present value/W_p of each state, and indicates that should the SREC market prices stay around 80% of each state's SACP going forward, then all of the states clearly have strong potential to affect residential SPV markets.

New Jersey has the most aggressive SREC policy with a Present Value over \$6.57/W_p, and Delaware's policy comes in second with a \$4.64 Present Value/W_p. In fact, in New Jersey the 2010 SPV price per W_p was \$7.10, thus this \$6.57 would offset almost the entire investment even before including other policies like Net Metering, the federal tax credit, and other policies. Massachusetts' SREC is also strong, and from 2010–2020 rivaling New Jersey's, but the 2020 carve-out end date detracts from its overall value. DC, Maryland, New Hampshire, and Ohio fall into a second tier.

The same table compares SREC policies against the other policies that make up each state's portfolio of solar incentives. All the SREC policies calculated can indeed be as strong as other policies, and their Present Values suggest that each of these incentives have the potential to be stronger even than the federal tax credit. Additionally, the table clearly shows that the strength of net metering is directly tied to the energy prices in each state. Ohio's low energy price makes its net metering incentive less effective, which explains why Ohio's overall package is lowest despite not having the lowest SREC potential.

5.3. Varying prices of SRECs

5.3.1. Auctions and spot prices

While the SREC potential is enormous, sometimes dwarfing the Present Value/W_p of the proven policies, in practice the Present Value/W_p is in fact possibly lower than that of the federal tax credit, and possibly \$0. The glaring limitation of this study is that SREC prices are variable, thus a long-term, 15-year financial analysis cannot take this price fluctuation into account. Therefore, this study using 80% of the SACP shows the potential the policies have at a practical maximum.

Spot prices and auction prices for SRECs give us a better understanding of the real value SRECs have at any moment in time. As of

Table 3
NPV and IRR of SREC policy by state.

State	NPV (\$)	IRR (%)
New Jersey	11,392.16	10.72
Massachusetts	3,569.70	6.54
Delaware	1,897.21	4.23
DC	−1,547.37	1.72
Maryland	−1,922.72	1.19
New Hampshire	−2,425.17	1.12
Ohio	−5,025.12	−2.35

Table 4
Present value per W_p for SREC vs. other policies.

State	SREC (\$)	Federal tax credit PV (\$)	Net metering (\$)	State tax credit (\$)
New Jersey	6.57	1.97	2.45	–
Massachusetts	4.37	1.94	2.40	0.24
Delaware	4.64	2.13	2.15	–
DC	4.13	2.19	2.29	–
Maryland	3.07	1.90	2.37	–
New Hampshire	2.21	1.82	2.53	–
Ohio	2.79	1.81	1.57	–

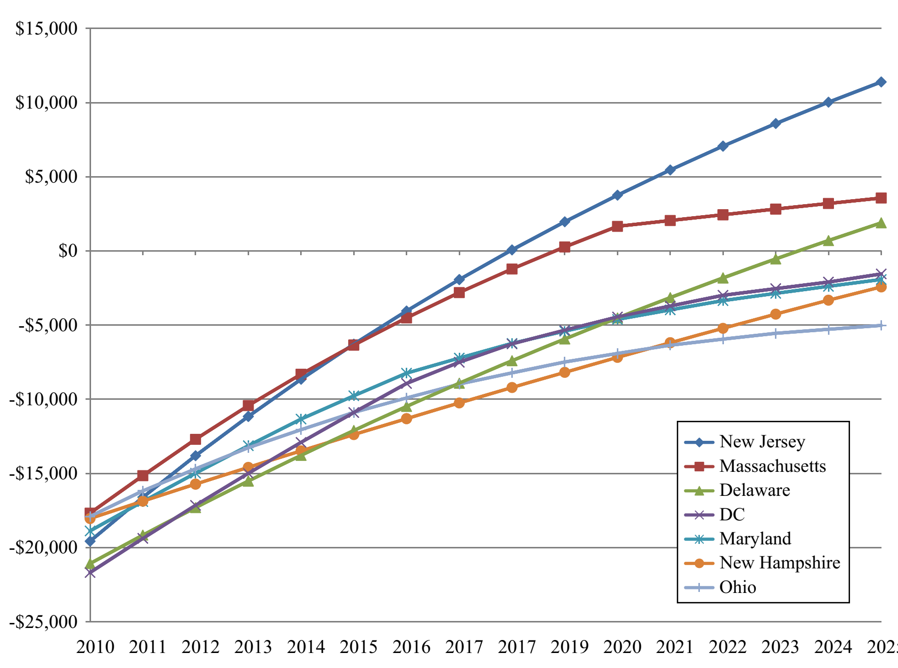

Fig. 1. Cumulative discounted cash flow comparison.

Table 5
December 3, 2011 SREC price and value landscape.

State	Spot price ($)[a]	Auction price ($)[b]	SACP (%)	Present value/W_p
Massachusetts	–	530.00	96.36	5.31
Ohio	320.00	370.00	92.50	3.26
New Jersey	235.00	225.00	33.30	2.77
DC	250.00	250.00	50.00	2.60
Maryland	200.00	210.00	52.50	2.04
Delaware	60.00	60.00	15.00	0.88
Pennsylvania	10.00	10.00	–	–

[a] Flett.
[b] SRECTrade.

December 3, 2011, Pennsylvania's SREC spot price was $10, due to an oversupplied market, down from $300 in July 2010 (Yonkin, 2011). Meanwhile, Ohio's SREC spot price was $320 (exactly 80% the SACP) (Flett, 2011). Table 5 shows the spot prices and auction prices along with the accompanying effects on SREC policy.

Most actual SREC market prices to SACP percentage is below 80%, while two are over 90%. Extrapolating the December 3, 2011 SACP percentage across the lifetime of SREC programs, the value of each program is different than the 80% assumption. Most notably it suggests Massachusetts' and Ohio's programs are more powerful than the previous calculations, while the other states' programs are less potent.

5.3.2. SREC floors

The changing prices make SRECs' true worth hard to accurately evaluate without a credible minimum price. There are two methods by which TGC policies can design floors into the SREC programs: government mandated floors, and private financing options leveraging the value of SRECs (Chupka, 2003). Currently only Massachusetts has a bottom price through its annual year-end auction clearing house.

Government mandated floors can be successful, as was found in Belgium (Verbruggen, 2004; Dusonchet and Telaretti, 2010a), and Massachusetts' clearing-house policy can give us a clearer view of a sort of baseline value for its SREC. Massachusetts' minimum SREC sales price of $300 applied to the model returns a Present Value/W_p of $2.71. This, when compared to other policies suggests there is real significance in MA's SRECs.

States are also pushing for utilities to sign contracts with SREC producers to give the producers a guaranteed price in an attempt to alleviate price fluctuation concerns. Some such contract offers have been equivalent to 40–60% the cost of installation, or 62% the SACP for SRECs over 5 or 10 years (DSIRE).

Additionally, private aggregators are beginning to offer a slew of financing plans for SPV systems in exchange for SRECs. Companies act as brokers for SRECs, and many offer guaranteed annuities in exchange for SRECs. The largest such aggregator offers an up-front payment of 10–25% the initial cost (depending on the state) in exchange for 10 years of SRECs, or a guaranteed annuity for 5 years for SRECs (although the price can be lower in states with lower SREC prices) (Sol Systems, 2011).

Assuming the average for solar insolation from the states examined (4 SRECs per year), we apply the Present Value/W_p measurement the on the 5-year $250 annuity they offer to some states, and the resulting Present Value per W_p is $1.17. This is lower than the federal tax credit policy, but is a guaranteed price, and should the Present Value/W_p be the $3.97 average, Sol Systems is making a healthy profit, and the residential SPV owner is sacrificing a large chunk of value for security. However, even at these prices, the $1.17 Present Value/$W_p$ is nothing to be scoffed at, and is only for the first 5 years of the SPV system's lifespan after which the SREC holder can sell SRECs generated in subsequent years.

6. Conclusion

This paper has presented a comparative analysis of the supporting mechanisms in the different states with SREC policies. The strength of each policy varies based on the size of the incentive, cost of residential SPV, electric energy price, and solar insolation. In the northeast, states where the energy price is higher are better suited for residential SPV, as they require less incentive beyond net metering. Meanwhile, in Ohio where the energy price is low, residential SPV is less attractive, and while the incentives make it more attractive, it is not enough to put residential SPV in competition with other forms of electricity production, within the first 15 years, at least before considering rebates and other incentives not covered in this analysis.

This paper further delves into SREC markets and measures the financial impact they can have on residential SPV. SREC prices are inherently difficult to value due to their changing price, but based on current conditions, the potential of SRECs are undeniable. In an attempt to place a value on SRECs, price floors would be ideal, and they are emerging in the form of aggregators that offer contracts for residences' SRECs. The true value of SRECs for residential SPV is in leveraging the future income through these aggregators. This value to date is roughly equivalent to or just below that of the federal tax credit

This comparative analysis has helped to:

- Assess the impact of incentives on residential SPV in states with solar set-asides and SREC policies;
- Gain insight into the intricacies of various SREC enforcement laws in the US;
- Place a quantifiable value on SREC policies to better express the worth and impact of these policies on residential SPV.

Acknowledgment

The financial support from National Science Council in Taiwan (NSC 100-2221-E-009-136) is acknowledged.

References

Barbose, G., Darghouth, N., Wiser, R., Seel, J., 2011. Tracking the Sun IV: An Historical Summary of the Installed Cost of Photovoltaics in the United States from 1998–2010. Ernest Orlando Lawrence Berkeley National Laboratory, Berkeley, CA (US). December. Available online from: 〈http://eetd.lbl.gov/ea/emp/reports/lbnl-5047e.pdf〉.

Borenstein, S., 2008. The market value and cost of solar photovoltaic electricity production. The Center for the Study of Energy Markets (CSEM) Working Paper Series. University of California, Berkely.

Buckman, G., 2011. The effectiveness of Renewable Portfolio Standard banding and carve-outs in supporting high-cost types of renewable electricity. Energy Policy 39, 4105–4114.

Chupka, M., 2003. Designing effective renewable energy markets. The Electricity Journal 16 (4), 46–57.

Denholm, P., Margolis, R.M., Ong, S., Roberts, B., 2009. Break-even cost for residential photovoltaics in the United States: key drivers and sensitivities. Technical Report NREL/TP-6A2-46909. Available online from: 〈http://www.nrel.gov/docs/fy10osti/46909.pdf〉.

DSIRE: US National Database of State Incentives for Renewable Energy. Interstate Renewable Energy Council. 〈http://www.dsireusa.org/〉. Viewed on November 30, 2011.

DTE Energy. Available online from 〈http://www.dteenergy.com/residentialCustomers/productsPrograms/customerChoice/electricChoice/generalFAQ.html〉.

Dusonchet, L., Telaretti, E., 2010a. Economic analysis of different supporting policies for the production of electrical energy by solar photovoltaics in eastern European Union countries. Energy Policy 38, 4011–4020.

Dusonchet, L., Telaretti, E., 2010b. Economic analysis of different supporting policies for the production of electrical energy by solar photovoltaics in western European Union countries. Energy Policy 38, 3297–3308.

Flett, M., 2011. First Energy Corp RFP for Pennsylvania SREC SPAECs Clears $199.10 for 10 Year – Flett Exchange. Available online from〈http://markets.flettexchange.com/2011/03/19/first-energy-corp-rfp-for-pennsylvania-srec-spaecs-clears-199-10-for-10-year/〉.

Hempling, S., Elefant, C., Cory, K., Porter, K., 2010. Renewable energy prices in state-level feed-in tariffs: federal law constraints and possible solutions. Technical Report NREL/TP-6A2-47408.

Koner, P.K., Dutta, V., Chopra, K.L., 2000. A comparative life cycle energy cost analysis of photovoltaic and fuel generator for load shedding application. Solar Energy Materials & Solar Cells 60, 309–322.

Lewis, F., Larry, P., 2010. Solar Cells and Their applications, 2nd edn. Wiley.

Lipp, J., 2007. Lessons for effective renewable electricity policy from Denmark, Germany and the United Kingdom. Energy Policy 35, 5481–5495.

Maryland Public Service Commission. SREC Posting Information. Available online from: 〈http://webapp.psc.state.md.us/intranet/sitesearch/postings_new.cfm〉.

Massachusetts Department of Energy Resources (DOER). RPS Solar Carve-Out – Energy and Environmental Affairs. Available online from: 〈http://www.mass.gov/?pageID=eoeeasubtopic&L=5&L0=Home&L1=Energy%2c+Utilities+%26+Clean+Technologies&L2=Renewable+Energy&L3=Solar&L4=RPS+Solar+Carve-Out&sid=Eoeea〉.

Menz, F.C., Vachon, S., 2006. The effectiveness of different policy regimes for promoting wind power: experiences from the states. Energy Policy 34, 1786–1796.

M.G.L. Ch.62. Section 6(d). General Laws of Massachusetts. Available online from 〈http://www.malegislature.gov/Laws/GeneralLaws/Search〉.

National Renewable Energy Laboratory. Open PV Project. Available online from: 〈http://openpv.nrel.gov/〉.

National Renewable Energy Laboratory. PVWATTS v. 1. Available online from: 〈http://rredc.nrel.gov/solar/calculators/PVWATTS/version1/〉.

New Jersey Board of Public Utilities (BPU). SREC Registration Program | NJ OCE Web Site. Available online from: 〈http://www.njcleanenergy.com/renewable-energy/programs/solar-renewable-energy-certificates-srec/new-jersey-solar-renewable-energy〉.

PJM. 2011 About GATS. Available online from: 〈http://www.pjm-eis.com/getting-started/about-GATS.aspx〉.

Pennsylvania Utilities Commission. Pennsylvania AEPS Alternative Energy Credit Program|Welcome. Available online from: 〈http://paaeps.com/credit/〉.

Senate Bill 388. North Carolina General Assembly. Available online from: 〈http://www.ncleg.net/gascripts/billlookup/billlookup.pl?Session=2009&BillID=S388〉.

Sol Systems, 2011. Solar REC (SREC) & Solar Financing Company. Available online from: 〈http://www.solsystemscompany.com/〉.

SRECTrade – Solar Renewable Energy Credit SREC Auction. 〈http://www.srectrade.com/〉.

Urlaub, I., 2011. Duke Energy Admits: No More Solar Needed in NC for REPS. NC Sustainable Energy Association. Available online from:〈http://energync.org/blog/ncsea-news/2011/06/14/duke-energy-admits-no-more-solar-needed-in-nc-for-reps/〉.

US Environmental Protection Agency. Renewable Portfolio Standards Fact Sheet. Available online from: 〈http://www.epa.gov/chp/state-policy/renewable_fs.html〉.

US Department of Energy. Federal Tax Credits for Energy Efficiency: ENERGY STAR. Available online from: 〈http://www.energystar.gov/index.cfm?c=tax_credits.tx_index〉.

US Energy Information Agency. 2010 Average Retail Energy (Table 5a). Available online from 〈http://www.eia.gov/electricity/data.cfm〉.

US Energy Information Administration. Electric Power Annual – U.S. Electric Industry Residential Average Retail Price of Electricity by State. Available online from: 〈http://www.eia.gov/cneaf/electricity/epa/fig7p5.html〉.

US Photovoltaics, 2010. Mayland SREC Market Overview 2010. Available online from〈http://www.uspvinc.com/main/sites/default/files/pdf/uspvnewsq110.pdf〉.

Verbruggen, A., 2004. Tradable green certificates in Flanders (Belgium). Energy Policy 32, 165–176.

Wiser, R., Barbose, G., Holt, E., 2010. Supporting Solar Power in Renewables Portfolio Standards: Experience from the United States. Prepared for the: US Department of Energy Office of Energy Efficiency and Renewable Energy Office of Electricity Delivery and Energy Reliability and the National Renewable Energy Laboratory and the Clean Energy States Alliance. LBNL-3984E. Lawrence Berkeley National Laboratory, Berkeley, CA. Available online from〈http://eetd.lbl.gov/ea/ems/reports/lbnl-3984e.pdf〉.

Yin, H., Powers, N., 2010. Do state renewable portfolio standards promote in-state renewable generation. Energy Policy 38, 1140–1149.

Yonkin, D., 2011. Why Spot SREC Prices Have Dropped in PA & Adjacent Markets. RenewableEnergyWorld.com. Available online from〈http://www.renewableenergyworld.com/rea/blog/post/2011/03/why-spot-srec-prices-have-dropped-in-pa-adjacent-markets〉.