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ORIGINAL ARTICLE

Community-based incentives for environmental protection: the case of green electricity

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Abstract This paper examines the effectiveness of using community-level rewards to subsidize environmental protection. Specifically, we study the Connecticut Clean Energy Communities (CCEC) program that provides mostly symbolic rewards in the form of municipal photovoltaic installations in proportion to the number of households that voluntarily purchase green electricity. We find that the program causes a 22 % increase in the number of households purchasing green electricity in CCEC municipalities. The pattern of results suggests that the CCEC leads to the mobilization of community-based recruitment campaigns that increase signup rates by up to 700 % around the period of initial qualification. We also find that a change in the marginal incentive created by the program has little consequence on signup behavior. The implication for policy is that community-based incentives can be effective, but the size of the subsidy itself appears less important. Finally, simple calculations based on CCEC up-front costs reveal upper-bound, cost-effectiveness measures of $570 per household signup, 6.7 ¢ per kilowatt-hour of annual green-electricity demand, and $113 per ton of annual carbon-dioxide emission reductions.

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1 Introduction

When considering market-based approaches to environmental policy, the instruments that typically come to mind are taxes and subsidies in various forms, along with systems of tradable permits that allow pollution emissions or the right to expropriate a resource. That economists tend to favor market-based approaches over command-and-control regulations, such as emission standards and technology requirements, is well-known. Economic theory tells us that under many circumstances, though not all, market-based approaches can achieve environmental outcomes at lower cost. Because they are generally less prescriptive, market-based approaches allow greater flexibility over the methods of compliance, while simultaneously creating incentives for further innovation. With tradable permits, there are also efficiencies that arise because of gains from trade in the permit markets themselves.

The unifying feature of all market-based approaches is to affect price signals in ways that more accurately reflect social costs or benefits, and thereby create incentives for greater environmental protection. Yet, the recent contributions of behavioral economics and studies with greater integration of economics with social psychology emphasize the important influence of social context on decision-making. The "identity economics" of Akerlof and Kranton (2000, 2010), for example, is based on the notion that individual preferences vary with social context, whereby identities and social norms interact to exert powerful influences on behavior. There is also the Nobel Prize winning work of Ostrom (2010) on solutions to the common-pool resource problem. Among the conditions that she finds for successfully solving collective action problems are not only the familiar notions of property rights and economic incentives, but also the need for institutional arrangements that recognize the importance of social networks (Ostrom 1990, 2000).

Recent studies in energy and environmental economics reinforce the importance of norms and social context. Allcott (2011) and Ayres et al. (2009) show that social comparisons through home energy reports on utility bills can promote conservation. According to both studies, households are spurred to decrease their energy consumption when they are informed that their consumption is greater than that of other comparable households. In related research, Costa and Kahn (2010) study heterogeneous effects and find that the "nudge" of social norms for household energy conservation works for liberals but can backfire for conservatives. Also with a focus on non-pecuniary incentives and norms, Harding and Hsiaw (2011) find that goal setting is an effective mechanism to induce energy efficiency and conservation in the residential sector. Jacobsen (2012) shows that climate change awareness campaigns that target certain communities lead to increased purchases of carbon offsets within those communities. Moreover, when households voluntarily purchase carbon offsets, different marketing strategies that appeal to either environmental concerns or social preferences

for future generations induce different behavioral responses, with the latter more consistent with conservation (Harding and Rapson 2012). Finally, Bollinger and Gillingham (2012) find that social interactions through peer effects play an important causal role in household decisions about the installation of solar photovoltaic (PV) panels.[1]

In this paper, we study a hybrid policy: a government subsidy of community-level rewards to both mobilize social capital and increase the incentives for households to purchase green electricity, which is electricity generated from renewable sources of energy. The Connecticut Clean Energy Communities (CCEC) program is a statewide initiative designed to incentivize households to voluntarily purchase green electricity at a price premium from one of two state approved providers. The CCEC operates at the municipality level for Connecticut towns that voluntarily join and meet basic qualification criteria (discussed later). Upon joining and qualifying for the program, municipalities receive free PV panels in proportion to the number of households that voluntarily purchase green electricity. The PV panels are then installed at public locations within the municipality, including town halls, schools, and libraries.

While the CCEC program takes a somewhat non-traditional approach to environmental protection, the program does aim to improve price signals in the way mentioned previously for market-based environmental policies. In effect, the CCEC program lowers the price of purchasing green electricity because of the additional community benefits associated with each purchase. In practice, this additional social benefit depends to a large degree on social groups mobilizing to inform the community about the existence of the program. Indeed, Connecticut residents and officials familiar with the program indicate that the success of the CCEC program has depended on the formation of community-based recruitment campaigns, often emerging through schools networks and other community organizations, that seek to raise awareness of the CCEC program and meet its eligibility requirements.

In what follows, we provide a systematic evaluation of the CCEC program. First, we take advantage of municipality-level data on household purchases of green electricity from June 2005 through December 2011 to determine whether the CCEC program increases household purchases of green electricity. Second, we examine patterns in the rate of new purchases to shed light on whether the CCEC program achieves its results, at least in part, through the mobilization of community-based recruitment campaigns aimed at meeting the program's primary eligibility threshold. Third, we exploit a change in the CCEC program's subsidy rate—how household purchases translate into community PV panels—to test whether the actual marginal incentive affects household purchases of green electricity. Finally, we conduct a simple cost-effectiveness analysis of the CCEC impacts on residential demand for green electricity in Connecticut.[2]

[1] While our focus here is on energy and environmental topics, many of these behaviors are consistent with the private provision of public goods. When it comes to privately provided public goods more generally, the importance of social networks is becoming similarly recognized. Recent examples in other contexts include DellaVigna et al. (2012), along with the papers cited therein, and the review article by Bowles and Polania-Reyes (2012).

[2] A preliminary study found that the CCEC program increased purchases of green electricity in participating municipalities (Kotchen 2010), but the present paper provides a more detailed and complete study in several

The results of this research contribute to the literature through program evaluation of a new form of market-based environmental policy: subsidizing pro-environmental behavior through community-level rewards. The application to green electricity is related to broader trends in the US economy. More than 1.4 million households voluntarily purchased green electricity in 2009, the same year that demand increased 7 % (Bird and Sumner 2010, 2011). While the percentage of households making these purchases remains very low, state governments and electric utilities are increasingly looking towards green-electricity programs as one way to change the mix of energy sources toward a larger share of renewables, and the potential role of community-based initiatives is now recognized (Berry 2010). Hence the results reported herein evaluate an innovative mechanism for stimulating demand for green electricity, along with providing evidence on acquisition costs of new customers. In doing so, the paper complements other studies on green-electricity programs that focus on the determinants of program participation (Clark et al. 2003; Kotchen and Moore 2007) and behavioral responses (Kotchen and Moore 2008; Jacobsen 2012).

We find that the CCEC program causes a 22 % increase in the number of households that purchase green electricity in CCEC municipalities. A strength of this estimate is that identification is based on within municipality variation and comparisons with other municipalities that qualify for the CCEC program but have not enrolled. We find that the CCEC boosts participation around the time of initial qualification—up to 700 %—rather than inducing a sustained level of more new signups. Yet, having the CCEC program itself is the important feature, rather than the precise marginal incentives it creates. The implication for policy is that community-based incentives can be effective, at least in part because they lead to the formation of community recruitment campaigns; and yet the size of the subsidy itself appears less important. Finally, simple calculations based on CCEC up-front costs reveal upper-bound, cost-effectiveness measures of $570 per household signup, for which there is an implied cost of 6.7 ¢ per kilowatt-hour (kWh) of annual green-electricity demand, and $113 per ton of annual carbon-dioxide emission reductions.

2 Background

In 2000, the Connecticut state legislature established the Connecticut Clean Energy Fund (hereafter CTFund) with the goal of increasing the supply and demand of renewable sources of energy within the state.[3] To that end, the CTFund has developed a number of programs and initiatives that encourage homeowners, companies, and municipalities to support clean energy. This paper focuses on two of the CTFund

Footnote 2 continued
ways. In this paper, we have two more years of data upon which to estimate the CCEC impacts, and the earlier analysis did not consider the timing of new participants, the effect of changing the subsidy rate, or any cost-effectiveness comparisons.

[3] The CTFund changed its name to the Clean Energy Finance and Investment Authority (CEFIA) in 2012, but we use the original name throughout the paper because the data used in our analysis is from the period before the name change. Current details about the CEFIA are available online at http://www.ctcleanenergy.com/.

programs: the *Connecticut Clean Energy Options* program (henceforth "Options program") and the *Connecticut Clean Energy Communities* (CCEC) program.

The Options program gives households the opportunity to voluntarily contribute toward the development of clean energy in Connecticut through their monthly electricity bills.[4] The Options program is effectively a state-sanctioned, green-electricity program that operates in collaboration with the state's primary regulated utilities of Connecticut Light and Power (CL&P) and United Illuminating (UI). Households that enroll in the Options program voluntarily agree to pay a per kWh surcharge on their monthly electricity bill, the proceeds of which are used to fund the development of renewable energy systems, such as wind and small-scale hydroelectric power. Households choose to pay a surcharge on either 50 or 100 % of their consumption. They must also choose a specific clean energy provider that receives their payment and is obligated to provide a quantity of clean energy equivalent to the aggregate usage of the customers it serves. During the period of our study, the two clean energy providers serving the Options program were Sterling Planet and Community Energy.[5] Throughout the duration of our study, the two providers offered a similar mix of wind and small-scale hydro sources of energy, and they charged slightly different surcharges of 1.19¢ and 1.3¢ per kWh, respectively. Connecticut households consume an average of 750 kWh per month, so participation in the program at the 100 %-level costs around $9.40 per month, or $112 per year. More than 26,000 households currently participate in the Options program, making it one of the leading green-electricity programs in the nation. Households that join the Options program also earn incentive "points" for their municipality as part of the CCEC program, to which we now turn.

At the same time the Options program was created in 2005, the CTFund established the CCEC program to stimulate demand for green electricity. The CCEC program is a community-based program designed to mobilize social networks that encourage participation in the Options program. The basic idea is that qualifying municipalities receive free PV panels in proportion to the number of households that purchase green electricity through the Options Program. The clean-energy technologies are then installed at highly visible, public locations within a municipality, including town halls, schools, and libraries.

A critical part of the CCEC program is the number of points that a municipality earns. Initially, residential signups at the 50 and 100 % levels counted as half a point and one point, respectively, but a signup at any level began counting as one point beginning in November 2008.[6] The points are important because they affect

[4] The Options program was established by the CTFund under the directive of the Connecticut Department of Public Utility Control (DPUC) decision in Docket No. 03-07-161. The Docket was in response to Public Act 03-135 that required the DPUC to establish an alternative transitional standard offer option for consumers that incorporated clean energy as the resource providing the electricity.

[5] Details about the two green-electricity providers that were partners with the CCEC program during the period that we study are available online at http://www.sterlingplanet.com/ and http://www.communityenergyinc.com/.

[6] Municipalities can also earn points through other means: commercial or industrial purchases of clean energy, the installation of clean energy systems within the municipality (excluding systems earned by municipalities through the CCEC program), and purchases of Green-e certified Renewable Energy Credits

whether a municipality qualifies as a "Clean Energy Community" and the number of PV installations a municipality earns.

In order for a municipality to qualify for the CCEC program, it must meet an initial threshold of either 100 points or a 10 % household participation rate, where the latter is designed to accommodate smaller municipalities. It turns out that satisfying this requirement has generally meant earning 100 points, as 52 out of the 57 municipalities that have earned 100 points did so before achieving a 10 % participation rate. Two other conditions are also necessary for a municipality to qualify for the CCEC program. One is that towns must make the "Municipality Clean Energy Pledge" (hereafter "Municipality Pledge") in which they commit to purchasing a share of their energy for municipality services from clean energy sources. In particular, a municipality must make a voluntary clean energy purchase of at least 14 % in 2011, 15 percent in 2012, 16 % in 2013, 17 % in 2014, and 18 percent in 2015.[7] While municipalities can make the pledge without making a clean energy purchase, CCEC qualification requires that municipalities actually follow through and make the purchases. The other qualification requirement is that a municipality must participate in the U.S. Environmental Protection Agency's (EPA) Community Energy Challenge, though this is never a binding constraint for CCEC status, as the program has no real stipulations. It is merely an agreement whereby the EPA will provide technical assistance to pledged communities for increasing energy efficiency and renewable energy use in schools, municipal buildings, and wastewater facilities.

Upon qualification for the CCEC program, points translate into the size of community PV installations paid for by the CTFund according to the following rules. Each 100 points is worth a PV installation of 1 kW capacity. Moreover, it was initially set up so that a municipality would earn an additional 1 kW capacity for each 2.5 % increment of its residential signup rate. For example, if a qualified municipality increases its residential participation rate in the Options program from 7.5 to 10 %, it earns another 1 kW of PV capacity over and above the amount it earns for points. This 2.5 % increment was, however, changed to 5 % in November 2008, the same time that residential signups at 50 % began counting as one point rather than half a point. Note that in Connecticut, for a representative central location (Hartford, the state's capital) a 1 kW PV panel is rated to generate 1,157 kWh per year, or approximately 13 % of the average electricity demand for a residential household.[8] The value of the CCEC incentive is thus mostly symbolic rather than itself generating a significant amount of renewable energy. Nevertheless, the general question guiding this research is whether such a symbolic incentive can have a meaningful effect on household purchases of green electricity through participation in the Options program.

If the CCEC incentives are to have an effect, it is, of course, necessary for households to be aware of the Options program and the incentives themselves. Accord-

Footnote 6 continued
(RECs). In practice, however, the majority of points accrue through residential signups, accounting for 71 % of the total points earned by all municipalities as of December 2011.

[7] The Municipality Clean Energy Pledge is the successor program to the 20 % by 2010 initiative, which challenged municipalities to purchase 20 % of their energy from renewable sources by 2010.

[8] This estimate was obtained using the National Renewable Energy Laboratory's PVWatts Viewer available at http://mapserve3.nrel.gov/PVWatts_Viewer/index.html.

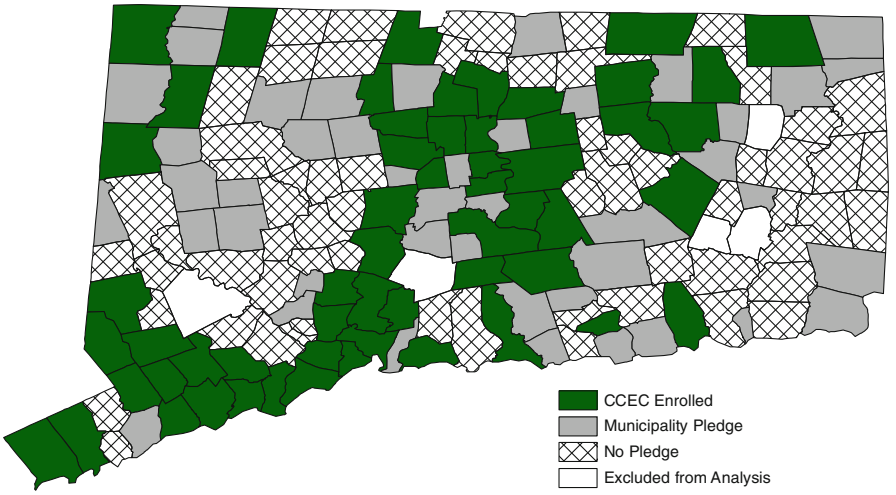

Fig. 1 Participation status in the CCEC program and Municipality Pledge of Connecticut municipalities as of December 2011

ingly, there have been several ways that CTFund has sought to increase awareness through public relations, marketing, and advertising campaigns. These efforts have included direct advertisements on the radio and television, as well as in newspapers. The programs have also been picked up through unpaid media, as evidenced by 700 newspaper articles that appeared in Connecticut in the second quarter of 2007 alone (Nexus Market Research 2008).[9] The Connecticut Department of Public Utility Control and the and the Public Utilities Regulatory Authority also require that utilities include billing inserts about the program twice a year, and the green electricity suppliers must also meet certain marketing and outreach requirements. Finally, and of particular importance for our analysis, the CTFund posts monthly updates about the number of municipal enrollments and points on the web at www.ctcleanenergy.com. This means that community members can obtain information about how current signups relate to the CCEC point thresholds and use the information to build community support and encourage signups.

Figure 1 is a map of Connecticut that indicates the status of each municipality, as of December 2011, with respect to whether it has made the Municipality Pledge and is enrolled in the CCEC program (recall that the former is necessary for the latter). Of the 164 municipalities that we consider, 57 have joined and qualify for the CEC program, 44 have made the Municipality Pledge but are not enrolled in the CCEC program, and 63 have neither made the Municipality Pledge nor enrolled in the CCEC program.[10]

[9] Some of this coverage is also the result of the CTFund encouraging local clean energy task forces and grant recipients to do marketing and outreach for the purpose of earning as much local media coverage as possible.

[10] Five municipalities are excluded from our analysis because they receive electrical service from a municipal provider that does not qualify for the CCEC program (the towns of Bozrah, Norwich, and

3 Data collection and preparation

We obtained the original data that the CTFund uses to administer the CCEC program. These data are maintained by NMR Group Inc., a consulting firm that provides ongoing monitoring and evaluation support for the CCEC program. The data that we use includes information for each municipality on the number of households that have signed up for the Options program at both the 50 and 100 % levels from June 2005 through December 2011.[11] The 2005 data are only available quarterly (June, September, and December), while we have monthly data beginning in 2006. We also know if—and when—each municipality made the Municipality Pledge and commenced enrollment in the CCEC program.[12] The dataset also includes the number of CCEC program points that a municipality has earned in each time period. In addition to the CTFund data, we obtained cross-sectional data from the Connecticut Economic Resource Center on the number of households in each municipality, as well as a municipality's median household income and percentage of college graduates for 2009, an intermediate year during our sample period. Finally, for the same year, we obtained data to create political variables that might capture the inclinations of each municipality towards the promotion of renewable energy. One variable is the percent of registered voters in the Democratic party among the two major parties of Democrat or Republican.[13] The other variable, which is designed to capture environmental preferences more directly, is the League of Conservation Voters (LCV) score of the state Senator representing the municipality.[14]

We merged and organized the data into a panel that includes 164 municipalities, 75 time periods, and 12,300 total observations. We create and define a number of variables related to household participation in the Options program for each municipality in each time period. *Total Participants, 50 % Participants,* and *100 % Participants* indicate the total number of households participating in the Options program overall and at each of the two different levels of participation. Corresponding with each of these variables, we also create a rate variable as the number of participants per 100 households (i.e., *Total Participation Rate, 50 % Participation Rate,* and *100 % Participation Rate*). To capture new signups in each period, we create *Total Signups, 50 % Signups,* and *100 % Signups* as the change in the number of households participating in the Options program relative to the previous period. We do not have data on monthly drop-outs from the Options program, but because we know from communication with program administrators that drop-outs are infrequent, period-to-period changes in participation are a close

Footnote 10 continued
Wallingford) or enrolled in the CCEC program for special circumstances negotiated with the CTFund (the towns of Hampton and Newtown). It is worth mentioning that the fundamental results of this paper do not change if we include the relatively small towns of Hampton and Newtown in the analysis.

11 Throughout the analysis, we pool the signups that occurred through both green-electricity providers, Sterling Planet and Community Energy.

12 Unfortunately, the historical data are not available on the timing of other factors related to meeting the requirements of the CCEC program, such as a municipality's clean energy purchases and participation in the EPA's Community Energy Challenge program, but this does not pose any problems for our analysis.

13 These data are available through the Office of the Connecticut Secretary of State, http://www.sots.ct.gov/sots.

14 These data are available through the Connecticut LCV, http://www.ctlcv.org.

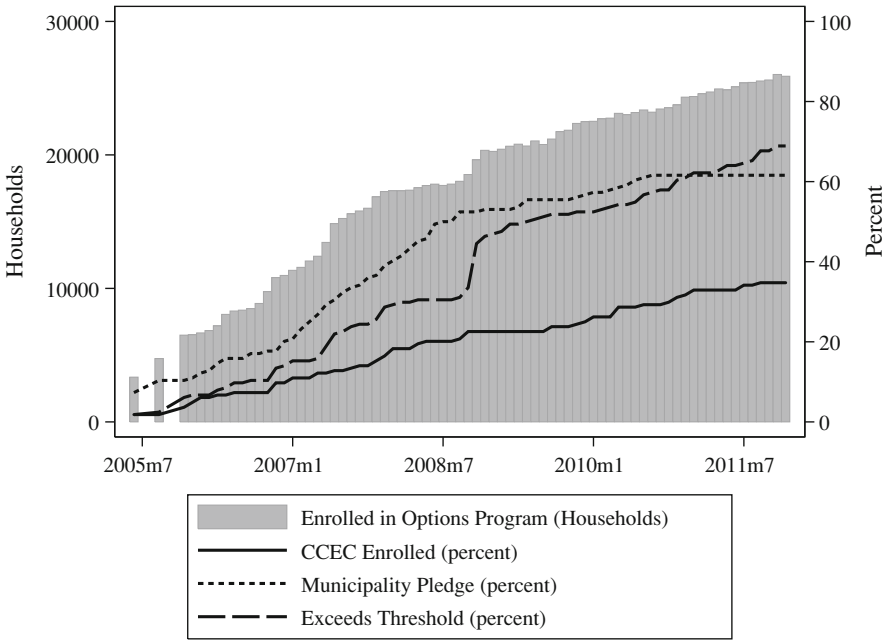

Fig. 2 Time trend of the number of households participating in the Options program and the percentage of municipalities participating in the CCEC program, having made the Municipality Pledge, and exceeding the qualification threshold

approximation for new signups, and we treat them as such in the analysis. For new signups, we create corresponding rate variables scaled per 100 households (i.e., *Total Signup Rate, 50 % Signup Rate,* and*100 % Signup Rate*).

We also create a set of time-varying variables that relate to a municipality's status with regard to qualifying for the CCEC program. *Municipality Pledge* is an indicator variable for whether a municipality has made the Municipality Pledge. *Exceeds Threshold* is an indicator variable for whether a municipality passes one of the thresholds (100 points or 10 % participation rate) required for enrollment in the CCEC program. Finally, *CCEC* is an indicator for whether the municipality is currently enrolled in the CCEC program. Note that *Municipality Pledge* and *Exceeds Threshold* must equal 1 if *CCEC* equals 1, as they are necessary conditions (though not sufficient) for CCEC enrollment.

Figure 2 presents information on aggregate time trends for some of the key variables. The grey bars indicate the total number of residential households participating in the Options Program by month. The counts sum households participating at the 50 and 100 % levels, though we will present the disaggregate trends later in the paper. Overall participation has risen substantially over time, increasing from 3,352 to 25,892 households. Figure 2 also illustrates the proportion of municipalities that are enrolled in the CCEC program, that have passed the 100-point or 10 % participation thresholds, and that have made the Municipality Pledge. These variables have also increased substantially over time as well. The proportion of municipalities exceeding the points

Table 1 Summary statistics

	All	CCEC enrolled	Not CCEC enrolled
Total participation rate	3.07	4.46	2.33
	(3.45)	(4.71)	(2.24)
50 % participation rate	0.45	0.60	0.37
	(0.55)	(0.72)	(0.41)
100 % participation rate	2.62	3.86	1.95
	(2.98)	(4.09)	(1.88)
CCEC points	225.35	417.23	123.13
	(281.27)	(391.43)	(101.79)
Exceeds threshold	0.69	1.00	0.52
	(0.46)	(0.00)	(0.50)
Municipality pledge	0.62	1.00	0.41
	(0.49)	(0.00)	(0.49)
Number of households	7,736	11,927	5,504
	(9,342)	(12,207)	(6,404)
Median household income	81,104	88,209	77,318
	(26,269)	(32,374)	(21,584)
College graduates (%)	46.69	53.96	42.81
	(14.57)	(14.25)	(13.25)
Democrat share (%)	57.21	61.28	55.04
	(12.33)	(13.53)	(11.11)
State senator's LCV score	91.70	91.81	91.64
	(7.29)	(7.48)	(7.22)
Observations	164	57	107

Notes Statistics reported are means (standard deviations) of the variables for the corresponding group of municipalities

threshold increased from 2 to 69 %, the proportion of those making the Municipality Pledge increased from 7 to 62 %, and the proportion of those enrolled in the CCEC program increased from 2 to 35 %. Note that the sharp increase in the proportion of municipalities exceeding the participation threshold occurs at the time that points awarded for household 50 % signups converted from one-half to one in November 2008.

Table 1 reports descriptive statistics for key variables. To focus on the useful comparisons, we report the statics for a cross-sectional snapshot of all variables in December 2011, the most recent period in the data. Among all municipalities, the mean participation rate in the Options program is just over 3 participants per 100 households, and 85 % of the participants have signed up at the 100 % rather than 50 % level. The mean number of households in all municipalities is 7,737, the mean of median household income is $81,104, and the percentage of individuals with at least a bachelor's degree is 47 %.

Table 1 also reports the descriptive statistics separately for municipalities that are enrolled in the CCEC program and those that are not. Note that CCEC enrolled municipalities have a higher average total participation rate (4.5 versus 2.3 participants per 100 households), as well as at both the 50 and 100 % signup rates, and investigating whether this relationship is causal is the focus of much of our analysis. There are other differences as well. Based on the comparison of means, municipalities enrolled in the CCEC program have about twice as many households, have incomes that are nearly $11,000 greater, and have a 10 % greater share of college graduates. The CCEC enrolled municipalities also have a greater share of registered Democrats, yet there is little variation in the LCV scores of the state Senators. Among the not CCEC enrolled municipalities, it is worth pointing out that 53 % have crossed the CCEC participation threshold, and 41 % have taken the Municipality Pledge. These features, as we will see, will prove useful to our empirical strategy for isolating the CCEC effect on participation in the Options program.

4 Statistical analysis

We organize discussion of our statistical methods and results around three questions: How does the CCEC program affect the level of residential participation in the Options program? Then, more specifically, is the effect of the program particularly evident during the time period when municipalities approach the primary eligibility threshold, as would be consistent with the mobilization of community-based campaigns to recruit signups? Lastly, to what extent, if any, do the marginal incentives of the CCEC program (i.e., points per signup that translate into community PV installations) influence signup patterns?

4.1 Participation levels

We begin with a cross-sectional examination of the overall participation rates in the Options program among municipalities. These models are useful for identifying variables that explain municipality participation rates and also provide a preliminary estimate of the CCEC effect on green-electricity signups. Using the most recent data for December 2011, we estimate regression models of the general form

$$TotalParticipationRate_i = f\begin{pmatrix} CCEC_i, ExceedsThreshold_i, \\ MunicipalityPledge_i, \mathbf{D}_i \end{pmatrix} + \varepsilon_i, \quad (1)$$

where i indexes municipalities; $\mathbf{D}_i$ is a vector of demographic variables (i.e., number of households in a municipality, median household income, percentage of residents with a college degree, percentage of registered Democrats, and LCV score of the municipality's state senator); and ε_i is a normally distributed error term. For purposes of comparison and interpretation, we estimate models with both linear and log-linear functional forms. The estimated coefficient on *CCEC* is of primary interest because it captures the relationship between a municipality's enrollment in the CCEC program and differences in the participation rate of households in the Options program.

Table 2 Cross-sectional models of the options program participation rate

	Linear model (1)	Log-linear model (2)
CCEC	1.03	0.216**
	(0.706)	(0.106)
Exceeds threshold	0.495	0.229**
	(0.345)	(0.108)
Municipality pledge	0.484	0.278**
	(0.429)	(0.107)
Number of households (1,000s)	−0.156***	−0.044***
	(0.041)	(0.006)
Median household income (10,000s)	−0.639***	−0.132***
	(0.245)	(0.026)
College graduates (%)	0.180***	0.048***
	(0.049)	(0.005)
Democrat share (%)	0.044*	0.003
	(0.027)	(0.005)
State senator's LCV score	−0.021	−0.004
	(0.025)	(0.006)
R-squared	0.422	0.702
Observations	164	164

Notes The dependent variable is Total Participation Rate. Standard errors are reported in parentheses. One, two, and three stars indicate 10 5, and 1 % significance, respectively

To reliably estimate the CCEC effect, it is important to include the variables of *Exceeds Threshold* and *Municipality Pledge* in the model. These variables help address potential endogeneity concerns. In addition to the CCEC program influencing participation rates, participation rates may influence enrollment in the CCEC program because sufficient participation is necessary for CCEC enrollment. When *Exceeds Threshold* is included as a control variable, the estimates are based on variation in the CCEC variable that is driven by factors other than participation in the Options program. In effect, identification of the CCEC effect is based on variation among only those municipalities that have crossed the qualification threshold.

The other potential concern is that some municipalities may be more or less concerned about energy and environmental issues in ways that are correlated with both the participation of households in the Options program and CCEC enrollment. The inclusion of *Municipality Pledge* helps address this concern because it can serve as a proxy for a municipality's concern about energy and environmental issues (in addition to the political variables); and while it too is a necessary condition for CCEC enrollment, there are many municipalities that have signed the Municipality Pledge but are not CCEC enrolled, because they have not yet made a clean energy purchase. Thus, inclusion of this variable means that identification of the CCEC effect is based on variation among only those municipalities that have signed the Municipality Pledge.

Table 2 reports the linear and log-linear results. For both specifications, the estimated effect of CCEC enrollment on participation rates is positive, but only statistically significant in the log-linear model, which implies that CCEC enrollment is associated with participation rates that are on average 22 % higher. Focusing on the log-linear model for other results, because it fits the data better with a R-squared of 0.7 versus 0.4, we find the expected results that exceeding the participation threshold and having taken the Municipality Pledge both result is higher participation rates. Moreover, the qualitative pattern of results for the demographic variables are such that larger and wealthier municipalities have lower participation rates, while those with more education have higher participation rates.[15] While there is some evidence that more registered Democrats increases participation, the statistical power of the political variables is weak.

While the cross-sectional estimates provide initial evidence that the CCEC program increases participation rates in the Options program, we now turn to fixed-effects models that take advantage of the panel feature of the dataset. These models provide a different estimation strategy, and comparison with the cross-sectional results enables a useful robustness check. The fixed-effects models identify the CCEC effect based on variation within municipalities, rather than between municipalities. Specifically, the model estimates how, on average, participation rates in the Options program within a municipality differs in periods with CCEC enrollment relative to pre-enrollment periods, controlling for time trends in participation that are common to all municipalities in Connecticut.

Specifically, we estimate fixed-effects regression models of the form

$$TotalParticipationRate_{it} = f\begin{pmatrix} CCEC_{it}, ExceedsThreshold_{it}, \\ MunicipalityPledge_{it}, \alpha_i, \gamma_t \end{pmatrix} + \varepsilon_{it}, \quad (2)$$

where i continues to index municipalities; t indexes each month-year; $\alpha_i$is a municipality-specific intercept that controls for time-invariant differences across municipalities; $\gamma_t$is a vector of dummy variables for each month-year that control for the time trend experienced uniformly by all municipalities; and ε_{it} is a normally distributed error term. As with the cross-sectional analysis, we estimate linear and log-linear models. To account for potential serial correlation when making statistical inference, we cluster all standard errors, for this model and all fixed-effects models throughout the paper, at the municipality level. Note that the models are estimated on a balanced panel where there are all monthly observations for all Connecticut municipalities.

We report the fixed-effects models in Table 3. For both specifications, *CCEC* has a positive and statistically significant effect on participation rates in the Options program. The linear model in column (1) indicates that CCEC enrollment is associated with 1.5 more participants per 100 households. The log-linear model in column (2)

[15] It is worth mentioning, however, that when education is excluded from the model, the coefficient on median household income is either statistically insignificant (linear model) or significant and positive (log-linear model), reflecting the high correlation among these variables and the importance of including both to avoid omitted variable bias.

Table 3 Fixed-effects models of the options program participation rate

	Linear Model (1)	Log-Linear Model (2)
CCEC	1.475**	0.218***
	(0.618)	(0.063)
Exceeds threshold	0.454**	0.088***
	(0.197)	(0.029)
Municipality pledge	0.194	0.028
	(0.168)	(0.036)
Municipality fixed effects	Yes	Yes
Month-year fixed effects	Yes	Yes
R-squared (within)	0.35	0.848
Observations	12,300	12,294

Notes The dependent variable is Total Participation Rate. Standard errors are reported in parentheses and are clustered by municipality. One, two, and three stars indicate 10, 5, and 1 % significance, respectively

produces an estimate that is very similar to the cross-sectional model: CCEC enrollment is associated with a 22 % increase in the participation rate. When interpreting these results, it is important to keep in mind, however, that these estimates apply to the participation rates in municipalities that are CCEC enrolled and not the participation rate in the Options program for the state as a whole. Later in the paper, when considering cost effectiveness of the CCEC program, we convert these changes in the participation rate to the actual number of household signups in Connecticut. At this point, though, other results to note for the fixed-effects models in Table 3 are that, not surprisingly, exceeding the participation threshold is associated with higher participation rates, but the affect of taking the Municipality Pledge is not statistically significant.

4.2 Signups around the time of CCEC qualification

We have seen evidence that the CCEC program increases household participation rates in the Options program. That is, a community-based incentive for PV installations spurs households to voluntary purchase green electricity. We now consider in more detail the timing of how the higher participation rates are achieved. Personal communication with CCEC program administrators points to the critical role of community leaders in organizing drives for signups in order to meet the initial CCEC qualification threshold of either 100 points or a 10 % participation rate. We therefore consider whether the community goal of CCEC enrollment caused a surge in signups around the time of passing the threshold for initial qualification. Evidence of a surge would lend further support to the conclusion that the CCEC incentive simulates demand for green electricity.

We begin by creating new variables that indicate each municipality's relative time from when it first crossed the CCEC qualification threshold. We focus our analysis

on the twelve months before and after the crossing point. Keep in mind, however, that the crossing point does not occur in the same month-year for each municipality, and some municipalities never cross the threshold. To capture this, we create 25 indicator variables for when an observation occurs relative to the period when a municipality first (if ever) crossed the threshold. The categories correspond to the number of months before crossing the threshold (-12 or more, and each month -11 through -1), the month of first crossing the threshold (centered as 0), and the number of months after crossing the threshold (each month 1 through 11, and 12 or more). If a municipality never crosses the threshold, all of the indicator variables equal zero.

Importantly, for this part of the analysis, we are not interested in the cumulative participation rate in the Options program, but rather in the signup rate that occurs in each month around the time of crossing the threshold. We thus use *Total Signup Rate*, which as described previously, is the net change in *Total Participation Rate* from one month to the next over the entire span of data. For completeness, we report that this variable has an overall mean of .035, which means that from month-to-month there is an average of 3.5 additional participants in the Options program (at either the 50 or 100 % levels) for every 10,000 households in a municipality. The question we consider is whether this signup rate exhibits a different pattern around the time of meeting the CCEC qualification threshold in those municipalities that seek enrollment in the CCEC program.

The final step before specifying our model is to recognize that not all municipalities that cross the qualification threshold ultimately enroll in the CCEC program. These municipalities may be either unaware of the CCEC program or simply not motivated to participate, despite the fact that a sufficient number of households within the municipality purchase green electricity through the Options program for CCEC qualification. We take advantage of this feature in the dataset as somewhat of a counterfactual. These municipalities are ones that cross the CCEC qualification threshold but would not be expected to respond to the CCEC incentives because they never enroll. The precise question we consider, therefore, is whether the two types of municipalities—eventually CCEC enrolled or never CCEC enrolled—exhibit different patterns in the signup rate around the qualification threshold.[16] To estimate these differences, we create two new time-invariant indicator variables of *CCEC Enrolled* and *Never CCEC*, which are mutually exclusive with one or the other characterizing each municipality.

With these new variables in hand, we estimate a fixed-effects model of the form

$$\begin{aligned} TotalSignupRate_{it} = \boldsymbol{\beta}\mathbf{T}_{it} \times CCEC \\ Enrolled_i + \boldsymbol{\varphi}\mathbf{T}_{it} \times NeverCCEC_i + \alpha_i + \gamma_t + \varepsilon_{it}, \end{aligned} \tag{3}$$

where $\mathbf{T}_{it}$ is the vector of indicators for the number of periods before and after a municipality first crossed the CCEC qualification threshold. The key feature of equation (3) is that β and ϕ provide estimates of how the signup rate differs among periods

[16] Some municipalities enroll in the CCEC program immediately upon meeting the qualification threshold, while others have delayed enrollment. While we first consider differences between municipalities that eventually enroll and those that never enroll, we will next investigate potential differences between municipalities with early and delayed enrollment.

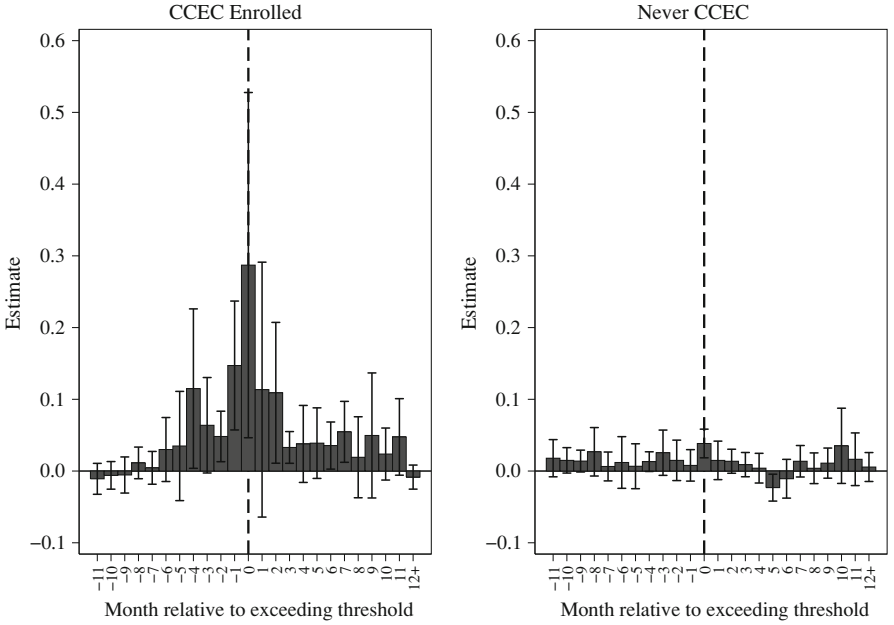

Fig. 3 The change in Options program signup rates around the period when municipalities first crossed the CCEC qualification threshold, by those enrolled and never enrolled

of interest and separately for the *CCEC Enrolled* and *Never CCEC* municipalities. The omitted category for each group is the period of -12 months or more, meaning that the estimated coefficients indicate the difference in a period's signup rate relative to the trend-adjusted signup rate during the entire period of more than a year before crossing the CCEC qualification threshold.

We report the estimated results of equation (3) graphically in Figure 3. We report results for the *CCEC Enrolled* and *Never CCEC* municipalities in two separate panels, yet the estimates are from the same regression model (with 12,136 observations and a within R-squared of 0.12). The bars correspond to the coefficient estimates, and we include the 95 % confidence intervals. Looking first at the *CCEC Enrolled* municipalities, there is a clear trend in the signup rate around the threshold: it ramps up about six months before, tapers off after, and appears to maintain a somewhat higher level almost a year out. To get a sense for this magnitude, the peak at period 0 implies an increased monthly signup rate of 0.29 participants per 100 households compared to the average signup rate more than a year earlier, at which time it was 0.051 for these municipalities. This comparison implies a 568 % increase in the signup rate. Turning now to the *Never CCEC* municipalities, the pattern is quite different: there is no surge in the signup rate, which appears to remain relatively constant over the 2 years illustrated in the graph.

We interpret these results as consist with the CCEC incentives having a positive effect on the signup rate for the Options program. Not only is there a surge in the participation rate in municipalities that were ultimately CCEC enrolled, we find no

such patterns in those municipalities that never enrolled even though they meet the qualification threshold. For the *Never CCEC* municipalities, having met the threshold can be explained by sufficient interest among households in the Options program apart from the CCEC incentive.

Though we do not report the results here, we also investigated whether the similar ramping-up pattern of signups occurs around the intensive marginal thresholds after CCEC enrollment, that is, the 200-, 300-, …and even up to 1,000-point threshold for at least 5 municipalities. At these different thresholds a similar pattern does not emerge showing that new enrollments ramp up prior to the point of crossing the threshold.

To further explore whether the CCEC program has the expected effect on signups, we take advantage of the fact that not all *CCEC Enrolled* municipalities enrolled immediately upon crossing the threshold. In fact, 32 % of the municipalities took more than 6 months to enroll after crossing the threshold because of the time it took them to fulfill the other CCEC requirements. We hypothesize that municipalities that experienced short delays (i.e., less than 6 months) between crossing the qualification threshold and joining the CCEC program were more likely to have increased signups occur around that time because their quick enrollment suggests that community leaders were more aware of the program requirements. We test this hypothesis with a further refinement on specification (3). Specifically, we estimate a set of coefficients for three rather than two groups. While *Never CCEC* remains the same, we split the *CCEC Enrolled* group into the *Short Delay* and *Long Delay* subsets based on whether enrollment occurred within six months or longer.

Figure 4 illustrates the three sets of coefficients from the expanded version of specification (3) (with 12,136 observations and a within R-squared of 0.14). Two observations are worth making. First, the pattern of signups for the *Long Delay* municipalities looks more similar to that for the *Never CCEC* group. Second, the surge in signups for the *Short Delay* group is even more pronounced, with the peak at roughly 0.42 additional signups compared to our previous estimate of 0.3, though the difference is not statistically different. In this case, the change is a 736 % increase from the period a year earlier for the relevant group, when the rate was 0.057 participants per 100 households. These results lend further support to the conclusion that the CCEC combined with awareness and community recruitment measures increase purchases of green-electricity, as those communities with more timely CCEC enrollment also exhibit the greatest ramp up in signups to achieve initial qualification.

4.3 The effect of marginal incentives

The evidence shown thus far makes a strong case that the CCEC program has a causal effect on participation rates in the Options program and on the signup rates for many municipalities around the time of initially qualifying for CCEC enrollment. We now consider how responsive signup rates are to the marginal incentive that the CCEC program offers to communities. Recall that under the initial structure of the CCEC

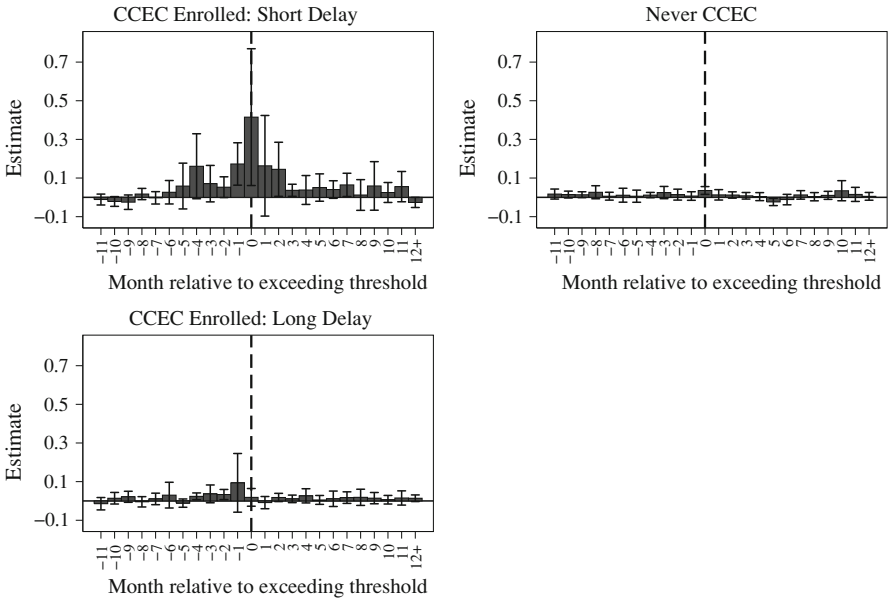

Fig. 4 The change in Options program signup rates around the period when municipalities first crossed the CCEC enrollment threshold, by those enrolled with a short or long delay, or never enrolled

program, household signups in the Options program at different levels counted for a different number of points awarded toward community PV installations. Specifically, household signups at the 50 and 100 % levels counted as one-half and one-full point, respectively. Beginning in November 2008, however, the structure changed so that signups at either level counted as one full point. The question we address is whether this change in the marginal incentive affects the propensity of households to signup at the 50 % level. To the extent that households are aware of the precise marginal incentive, it is reasonable to expect a greater propensity for 50 % signups after they become worth the same number of points as 100 % signups.

We first examine the trends graphically. Figure 5 shows time trends in the total number of participants separately for 50 and 100 % signups and for *CCEC Enrolled* and *Never CCEC* municipalities. The vertical line indicates the timing of the changed marginal incentive for 50 % signups. One observation to make is that the figure reinforces the results shown previously. It is clear that, at both levels of participation, there is a noticeably different increase over time in CCEC enrolled municipalities. But more to the point of the question at hand, there does not appear to be a noticeable change in the trend of 50 % signups, either on its own or relative to the 100 % signups.

We nevertheless test for an effect more formally with a regression model. In doing so, we continue to focus on signup rates rater than participation rates and use the variables *50 % Signup Rate* and *100 % Signup Rate*, which as defined previously, are the change in the participation rate of the respective variable from one month to the next over the entire span of data. *After Period* is an indicator variable for the months

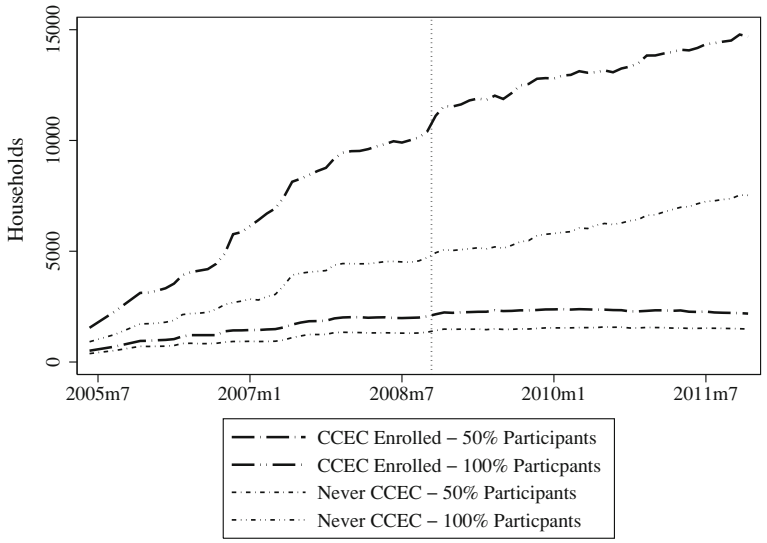

Fig. 5 Time trend of the number of households participating in the Options program at the 50 and 100 % levels, by CCEC enrollment status and before-after a change in the marginal CCEC incentive on November 2008 (indicated with the vertical line)

after the CCEC program changes the marginal incentive (i.e., months after November 2008).

We begin with a fixed-effects model to estimate the relationship between *50 % Signup Rate* and *100 % Signup Rate*, before and after the changed incentive:

$$50\,\%SignupRate_{it} = \beta 100\,\%SignupRate_{it} + \delta 100\,\%SignupRate_{it} \times AfterPeriod_i + \alpha_i + \gamma_t + \varepsilon_{it} \quad (4)$$

With the coefficients β andδ, this model estimates the within-municipality relationship between the number of signups at the different levels and determines whether the relationship is different after the incentive change. The results are reported in the column (1) of Table 4. Not surprisingly, we find, with a high degree of statistical significance, that the number of 100 % signups is positively associated with the number of 50 % signups. The relationship does not, however, differ between the before and after periods. If households were more likely to signup at the 50 % level, due to the incentive change, the expected sign on δ would be positive, indicating that there would be more new 50 % for each new 100 % signup. We find that it is positive, yet the estimate is not statistically different from zero.

We next consider whether the before-after difference differs between *CCEC Enrolled* and *Never CCEC* municipalities. While the changed incentive might be expected to affect the 50 % signups in all municipalities—those enrolled and those intending to enroll in the CCEC program—the effect could be stronger in *CCEC Enrolled* municipalities since they have a demonstrated interest in the program and immediately face the marginal incentives because of the way that points translate into

Table 4 Fixed-effects models of the 50 % signup rate and the change in the marginal CCEC incentive in November 2008

	(1)	(2)
100 % Signup rate	0.068***	0.049***
	(0.020)	(0.016)
100 % Signup rate × After period	0.037	−0.009
	(0.071)	(0.033)
100 % Signup rate × After period × CCEC enrolled		0.112
		(0.088)
After period × CCEC enrolled		−.005*
		(0.003)
Municipality fixed effects	Yes	Yes
Month-year fixed effects	Yes	Yes
R-squared (within)	0.072	0.139
Observations	12,136	12,136

Notes The dependent variable is 50 % Signup Rate. Standard errors are reported in parentheses and are clustered by municipality. One, two, and three stars indicate 10 %, 5-percent, and 1 % significance, respectively

the size of earned PV installations. The final regression model includes two additional interactions:

$$\begin{aligned} 50\,\%SignupRate_{it} = {} & \beta 100\,\%SignupRate_{it} + \delta 100\,\%SignupRate_{it} \\ & \times AfterPeriod_i + \mu 100\,\%SignupRate_{it} \times AfterPeriod_i \\ & \times CCECEnrolled_{it} + \lambda AfterPeriod_i \\ & \times CCECEnrolled_{it} + \alpha_i + \gamma_t + \varepsilon_{it} \end{aligned} \tag{5}$$

The new variables are on the second and third lines. The coefficient μ provides an estimate of how the difference in the before-after relationship between levels of participation might differ between municipalities when enrolled or not in the CCEC. The estimate of λ tests for whether the two types of municipalities differ in the number of 50 % signups, before and after, and for reasons not captured by the number of 100 % signups. These results are reported in column (2) of Table 4. We find no statistically significant results for variables that include interactions with *100 % Signup Rate*. We do, however, find that after controlling for the common time trend and the 100 % signup rate in the municipality, those that are CCEC enrolled experience a decrease in the 50 % signup rate after the incentive change. These results, along with those reported previously, are consistent with the conclusion that household signups into the Options program are not responsive to the marginal points incentive of the CCEC program, despite the fact that the CCEC program stimulates overall participation.

5 Discussion and conclusion

In this paper, we examine the effectiveness of using community-based incentives to promote environmental protection. In particular, we examine the CCEC program, which is intended to stimulate household demand for green electricity throughout Connecticut. The mechanism, as we have described, is mostly symbolic rewards in the form of small-scale municipal PV installations in proportion to the number of households that purchase green electricity. The starting-point question of our analysis is whether the program has any effect and whether the results are consistent with community recruitment efforts to increase the purchases of green electricity.

Using 7 years of monthly data on green-electricity signups for all municipalities in the state, we find clear evidence that the program does have an effect, but the take-away message is a bit more nuanced. Thirty-six percent of the municipalities in Connecticut have met the requirements of the CCEC program. Within these municipalities, our best estimate for the CCEC effect is a 22 % increase in the number of households that purchase green electricity through the Options program. We also find the CCEC boost in participation happens around the time that municipalities initially cross the qualification threshold, which suggests that the program mobilizes communities to undertake targeted drives to meet its requirements. In particular, at the critical point of meeting the threshold, signup rates increase by over 700 % for some municipalities. We do not, however, find similar surges in participation around incentive thresholds at the intensive margin. Moreover, we find little evidence that the precise marginal incentive for each signup makes a difference. When the subsidy rate for new PV installations doubled for household signups at the 50 % level, making them equivalent to 100 % signups, we find no change in the propensity of signups favoring the less expensive 50 % level. The general implications for policy are the following: subsidizing a program using community-level rewards can be effective; the amount of the subsidy itself is less important; and the impacts that arise appear to occur, at least in part, because of the formation of community recruitment efforts. The last finding suggests that other programs with similar objectives should seek to find ways for encouraging community mobilization through various channels.

Beyond changes in the participation rate, how cost-effective is the CCEC program? We answer this question with a few simple calculations. Our estimate of a 22 % increase in participation in CCEC municipalities translates into 3,043 additional signups, equivalent to 12 % of all residential signups in Connecticut. Using the fact that mean residential electricity consumption is 750 kWh/month and the observed fraction of 50 and 100 % signups in CCEC municipalities in December 2011, we conclude that the CCEC program is responsible for increasing demand for green electricity of 25,607 megawatt hours of electricity per year. According to the EPA calculations for the northeast region, this quantity of green electricity reduces carbon dioxide emissions by 15,427 tons per year.[17] Achieving these benefits, however, comes at the cost of PV installations within communities. The CCEC program has funded the installation of 193 one-kW capacity PV panels attributable to residential signups in

[17] This calculation is made using the EPA's Green Power Equivalency Calculator a for the NEWE electricity generation region. The tool is available online at http://www.epa.gov/greenpower/pubs/calculator.htm.

the Options program, and the estimated cost per installation is $9,000. Hence simple calculations based on CCEC up-front costs reveal costs-effectiveness measures of $570 per household signup, 6.7 /c/kWh of annual green-electricity demand, and $113 per ton of annual carbon-dioxide emission reductions.[18] Note that the increased green-electricity demand and reduced carbon dioxide emissions are recurring annual benefits that arise from the one-time upfront costs. It is also worth mentioning that these cost-effectiveness calculations should be interpreted as an upper-bound because they focus on residential signups and do not account for the effect of CCEC public education and awareness campaigns that affected all municipalities in the state, nor do they account for the requisite green-electricity purchases of municipal governments. Additionally, households that sign up for the program receive intrinsic benefits in one form or another, and these are not considered in cost-effectiveness calculations.

We conclude reiterating the point that the use of community-based incentives has a place among new forms of environmental policy. The approach combines market-based incentives with more localized social networks to promote environmental protection. Consequently, the approach is also consistent with new forms of environmental policy that integrate economic theory on clubs and privately provided public goods (Kotchen 2012). While such voluntary programs can make meaningful contributions to environmental protection, they are unlikely to displace more centralized policies because the incentive for free riding is difficult to fully overcome. Nevertheless, our evaluation of green-electricity programs in Connecticut shows that community-based incentives can be effective. The appeal of these programs relative to other policy options depends on the responsiveness of a community, and further research that sheds light on the types of communities that are most responsive to community-based incentives will help improve the design of future policies.

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[18] These figures reflect average cost effectiveness. Variation in cost-effectiveness across municipalities likely exists depending on a municipality's population size, average electricity consumption, and propensity to sign-up at the 50 or 100 % level. We report the overall state average because the program takes place at the state level.

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