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Abstract

Many US state electric utilities are unlikely to meet greenhouse-gas emission targets despite natural-gas conversion, investment, conservation, and support for renewables. Home rooftop solar (HRS) is one renewable program where subsidies have not led to broad market adoption. In contrast to extensive survey research that assisted utilities in planning Green Pricing (GP) programs, environmental economic research has provided little guidance to HRS policy. This paper attempts to overcome the unique set of factors – house condition, financing barriers, and lifestyle preferences – that have deterred HRS field survey research. This paper builds on the literature on household willingness to pay (WTP) for GP in order to conduct a large-data experimental survey.

The authors partnered with a city-run public utility in Florida to mail field surveys to nearly 25,000 electricity customers. They sent out sixteen randomized versions of a modified 4 x 4 design that investigated WTP for solar hot water, large and small photovoltaic (PV) rooftop systems, and a GP control group, each at four different prices. The authors found that homeowner HRS and GP participation rates are comparable. Education, income, and environmental support also display the expected direct impact on WTP for HRS and GP. However, price only tests significant among college-educated, pro-environment respondents likely to be predisposed toward solar.

The papers finds that annual residential charges comparable to those for GP programs would attract HRS adoptions that substantially reduce Florida's emission target shortfalls. The authors show these low customer premiums could become viable under current rebates if combined with expected HRS systems price declines and risk-lessening third-party ownership.

Keywords: home electric generation, rooftop solar, photovoltaic, solar hot water, net metering.
JEL Classification: Q51.

Introduction

Many US states and their electric utilities have signed on to the greenhouse gas emission goals of the National Action Plan for Energy Efficiency (NAPEE, 2008). However, utilities in Florida and most other states are increasingly unlikely to meet these target emission levels despite conversion to natural gas, phasing out inefficient plants, conservation promotions, and initiating Green Pricing (GP) and rooftop solar power (HRS) generation programs. For Florida utilities, those targets are return to 2000 emission levels by 2017 and to 1990 levels by 2025.

HRS consists of solar hot water and photovoltaic (PV) rooftop systems that lessen electricity generated by coal or natural gas. Yet HRS is one renewable program where subsidies and net metering have not led to broad market adoption (Jacobssen et al., 2004). And unlike the wealth of survey research that assisted utilities in planning Green Pricing (GP) programs, environmental economic research has provided little guidance to HRS policy.

The literature on contingent valuation (CV) modeling and survey methodology to estimate by hedonic pricing model the willingness to pay (WTP) seldom considers HRS. Instead, hedonic modeling has focused on Green Pricing programs (GP) where residential utility customers contribute to their electricity suppliers to construct renewable energy or purchase renewable electricity off the national grid (Mitchell and Carson, 1989).

Although utility companies increasingly offer GP (www.eere.energy.gov), participation of 1% (Bird et al., 2004) led utilities to fund CV survey research. These hedonic pricing studies successfully predicted WTP and identified factors that motivate consumers to participate in green-electricity programs (Byrnes et al., 1999; Ethier et al., 2000; Roe et al., 2001; Menges et al., 2005; Kotchen and Moore, 2007; Borchers et al., 2007; Whitehead and Cherry, 2007).

Several factors account for unavailability of HRS studies in survey research. First, while signing up for GP only affects your monthly bill and participation easily canceled, HRS involves a substantial, long-term financial commitment and payback uncertainties associated with future utility cost and improving rooftop technologies. The invasiveness of installing HRS systems also may adversely affect residential appearance or impose lifestyles changes. Concerns about these factors may deter homeowners from converting to solar or make utilities reticent to commit to HRS programs for their customers.

Institutional barriers also delayed CV survey research on HRS demand. Rooftop metropolitan PV systems necessitate the utility hook up to supply external power needs during cloudy and evening hours. Whenever home systems produced power in excess of their needs, utilities discouraged home electric generation by buying back HRS surpluses at low wholesale rate. Net Metering regulations finally ended this practice, requiring utilities to buy back home-generated electricity at the same price they charge those customers. Other bureaucratic barriers were delays in training and certification of solar contractors, inspections and permitting, application and qualification for rebates, and building code revisions. These contributed to institutional risks and resulted in HRS remaining rare in the U.S. communities.

This paper attempts to overcome the unique set of barrier to conducting HRS field survey studies so we can better understand homeowners' adoption decisions. We build on the extensive literature on household willingness to pay (WTP) for GP in order to conduct a large-data experimental survey for the customer base of a Sunbelt city's electrical utility. We also hope to shed light on whether annual residential charges comparable to those for GP programs would be financially feasible as well as attracting HRS adoptions that substantially reduce Florida's anticipated emission target shortfalls.

We begin the paper by describing the survey design and questionnaire instrument, adapt state-of-the-art survey techniques to WTP for renewable power, and identify methodological concerns particular to HRS survey design. We next report probit regression results for home solar, test for homogeneity among the survey design cells, and identify similarities with results from the GP control group analysis and GP literature. An assessment is conducted of HRS program viability and ability to help utilities achieve their greenhouse gas emissions goals. The paper concludes by summarizing findings and public policy implications, and opportunities for follow-up research.

2. Survey design, variables and bias

The study implemented a 4 x 4 randomized block design (Table 1), consisting of four renewable energy customer-support programs and four levels of participant costs. The 16 distinct survey versions differed only by the renewable support program considered – large PV and small PV solar hot water rooftop systems, and a green pricing program (the control group) – and by one of four alternative customer participation costs arrayed with 1:2:3:4 ratios. For solar hot water or PV adoption, the survey represents homeowner costs as average annual incremental charges for installation, financing, operation, and maintenance over the life of the system, net of government subsidies. The design centered costs (Table 1) at levels to elicit similar participation rates as Green Pricing studies in communities with incomes comparable to the target population[1].

[1] Note: Design costs do not measure homeowner "premiums" to add HRS (above utility rates) because (1) any premium is likely to narrow, so current premium would tie results to outdated market conditions, and (2) the objective is a private WTP portion of the solar premium that achieves utility targets with minimal subsidies.

Table 1. Components of 4 x 4 split-sample design of homeowner survey

Solar programs studied	Participant cost (Incremental $/year)			
Solar hot water system	$30	$60	$90	$120
Small photovoltaic system	$60	$120	$180	$240
Large photovoltaic system	$90	$180	$270	$360
Green pricing plan (control group)	$60	$120	$180	$240

The municipal utility[2] mailed out surveys with December 2007 monthly bills to all active electricity customers and the last responses received in mid-February 2008. This double-blind survey[3] reached the targeted 6500 single-family, owner-occupied, detached-dwelling homeowners for whom HRS is an option[4]. The 28% response rate was sufficient to conduct probit regression tests on each of the survey design cells[5].

2.1. Variables in the model. The survey contained questions to elicit responses on the probit regression variables (Table 2). We explain the *Yes5+* and *Yes7+* later in this section. The WTP is program participation cost *Cost/Yr* randomly assigned respondents.

Table 2. Variable names and descriptions

Dichotomous choice: agree to purchase or sign up for solar program	
Yes5+	Willing to participate with certainty level 5 or more
Yes7+	Willing to participate with certainty level 7 or more
Regressors: program cost, environmental attitudes and actions, demographics	
Cost/Yr	Net cost of solar program (after subsidies)
BuyEnvir	Dummy: "Often buy environmentally-friendly products"
Envir'ist	Dummy: "Consider myself an environmentalist"
RedOilDep	Dummy: "We must reduce our dependence on foreign oil"
CutEmit	Dummy: "We must cut greenhouse gas emissions"
Age 50-64	Age dummy: 50 to 64 years
Age > 65	Age dummy: at least 65 years
4YrColl	Education dummy: 4-year college degree or more
Inc 35-69K	Income dummy: $35,000 to $70,000
Inc > 70K	Income dummy: at least $70,000

Tastes and preferences for supporting renewable, clean energy are measured by four attitudinal and behavior variables. *BuyEnvir* measures environmental behavior in market decisions. The *Envir'ist* variable measures broader environmental attitudes and

[2] The Utilities Commission, City of New Smyrna Beach services that city and nearby populations.
[3] Utility employees inserted randomized, pre-folded questionnaires in billing envelopes, and respondents were not informed about the existence of 15 other survey versions.
[4] Condos, duplexes, rental units, etc. are generally prevented from unilaterally installing HRS.
[5] The higher response yield resulted from advance customer notification and publicity; survey legitimacy conferred by the university-utility partnership; customer assurances of confidentiality and grant financing of the study; single-sheet questionnaire compactness; pre-tested clarity of the survey instrument; demonstrated record of support for solar energy by the utility; and convenient submission alternatives (options of return in bill mailer or via drop box).

behavior as reflected in self-perceptions. The attitude variable *CutEmit* measures public concerns about greenhouse emissions, which may prompt utility customers to fund renewable energy. Finally, the *RedOilDep* attitudinal variable is included because a common misperception is that cutting emissions also reduces dependence on foreign oil. GP studies often report significance for environmental attitudes and behavior (e.g., Champ and Bishop, 2001; Roe et al., 2001; Rose et al., 2002; Menges et al., 2005; Wiser, 2007)[1]. In fact, Kotchen and Moore (2007) reported environmental attitudes as their only significant variable. Direct relationships on WTP are anticipated for each of these variables.

The regression also includes broader taste and preference measures of age and education, similar to those in GP survey studies by Wiser (2007), Champ and Bishop (2001) and Kotchen and Moore (2007). *Age 50-64* and *Age > 65* account for generational differences in attitudes and awareness that seem pervasive with environmental, energy, and global policy issues relating to renewable energy programs. Age also captures life stages that may affect market decisions toward risk-taking, investment, and overall change, which could affect the decision to install home solar. Seniors are more risk averse and have values shaped before the environmental awareness era, so we anticipate inverse impact on WTP from *Age > 65*.

The other potential demographic candidate is *4YrColl*. Environmental and energy issues involve complex science and economic concepts and analysis that may confuse those lacking a college education. College also broadens viewpoints of students, making them more accessible to new, different ideas. College-educated are more informed and well read, and tend to have longer time horizons consistent with concerns about climate change and energy resources. Thus, we expect direct effects from *4YrColl*.

Lastly, household income is represented by *Inc35-69K*. Income in environmental program studies dates to Ritchie et al. (1981) and is standard for GP studies. Environmental goods are luxuries with demand sensitive to income. WTP is especially constrained for pricey rooftop PV, so direct effects are expected for *Inc > 70K* and perhaps *Inc35-69K*.

HRS involves major investment, risks, and complex information issues not associated with GP program participation. Under these added installation barriers, WTP may be near zero among respondent groups less familiar with or less sympathetic toward environmental issues and among those unable to undertake financial risk or unwilling to make long-term commitments. For example, Allen and Soskin (1993) report that only households with prior experience using a recycling center responded to price incentive coupons. Analogous prescriptive criteria may be required for HRS. We will test whether price incentives only affect groups predisposed toward HRS, particularly for those with a college education or positive environmental attitudes.

2.2. Special factors to the HRS model. WTP for HRS is likely to be subject to similar variables as those in GP studies. The question is whether we should include factors distinct to modeling HRS. Clearly, WTP for home solar may involve several types of considerations not present in the decision to opt for a GP program. These HRS-specific factors stem from the long-term, major investment commitment required of homeowners as well as possible lifestyle and home aesthetics impact. In contrast, participants in a GP program may drop out, make no financial commitment, and experience no invasive changes to their home or lifestyle. Therefore, we specify an enhanced model with situational and demographic factors (Table 3) potentially relevant to home solar WTP. Information on these variables was elicited from questions in the survey instrument. Section 3 will contrast the standard and enhanced models and explore possible specification bias.

Table 3. Factors in enhanced model potentially relevant to solar home decision

Move10+	Not moved within past 10 years
Stay	Plan to stay in current house for foreseeable future
Sqft < 1800	Total area of house < 1800 square feet
Sqft2800+	Total area of house 2800+ square feet
Built < 1970	House built < 1970
Built1990+	House built 1990+
Roof10+	Current roof covering 10+ years old
RoofCat3	Roof withstand Category 3 hurricane (111-130 mph winds)
AC10+	Air conditioner 10+ years old
Imprv < 10	< $10,000 spent on major home improvements
Imprv20+	$20,000+ spent on major home improvements
ExtApp	Very concerned about how home exterior appears to neighbors
ChildGrnd	Any grandchildren or have children under 18
Resid0-1	< 2 year-round residents in household
Resid4+	4+ year-round residents in household

Two variables proxy for how attached respondents feel toward their homes. *Move10+* identifies lengthier home tenures while *Stay* identifies prospects for continuing tenure. Home improvements intended to help sell a house are apt to be different from those intended for current homeowners' enjoyment. Sellers make cosmetic upgrades with granite counters

[1] Environmental questions excluded from analysis were ownership of a hybrid vehicle and environmental group membership, which rarely occurred; and *brags about conservation savings* and *buys energy-saving bulbs* which were uncorrelated with other environmental measures.

and stainless steel appliances because an outmoded kitchen is often a deal breaker. However, homeowners may rationally choose major home improvements with low resale return if they are attached to their home and plan on staying, where home solar fits on the spectrum of affecting sales to resident user value is unknown, but home attachment variables may clarify.

Home size and condition occupy six measures that may affect WTP for HRS. Two size variables, *Sqft<1800* and *Sqft2800+*, proxy for property value but also home electric usage. Homes are the largest investment and net worth component for most households. Larger size may represent greater equity to finance HRS. Larger homes have higher electric bills to benefit from home solar but also require higher cost solar installations for a given percent reduction in those bills. Moreover, the decision to live in a larger home may constitute a revealed preference for a wasteful energy lifestyle.

Built<1970 and *Built1990+* are measures of home age. Owners of older homes may be less likely to install HRS because there are few lower-cost conservation alternatives available such as insulating or updating. Newer homes tend to be in better condition and expected to retain that advantage (over older homes), thus making them sounder, lower maintenance investments for HRS.

By contrast, an older roof (*Roof10+*) will soon need replacement, at which time a HRS installation could enjoy economies of scope. Bundling two installations also shortens installation time and disruptions. Combining re-roofing with a solar panel install results in a slimmer hurricane wind profile and improved aesthetic look of the home. However, older roofs may indicate repair procrastinators live there. Furthermore, re-roofing is costly, perhaps deterring home solar investment.

Ability to withstand windstorm damage (*RoofCat3*) may increase WTP. If homeowners doubt the roof's structural integrity, HRS will be a riskier investment. Like re-roofing, strengthening roof structure against hurricanes may benefit from scope economies. Conversely, HRS and wind protection may be competing expenses, reducing WTP for solar in coastal impact zones like the study area.

Homes with older air conditioning systems (*AC10+*) are nearer a replacement decision, which could involve adding home solar while downsizing the peak capacity of their new AC. Homes with newer, more efficient systems now required get locked into their expensive, hi-capacity air conditioner choice and have less incentive to opt for solar.

Prior home improvement spending (*Imprv<10* and *Imprv20+*) may reveal preferences for home upgrades, including solar, rather than financial assets, nondurables spending, or vehicles and other durables.

Unlike GP program participation, installation of HRS affects the look of a house. If homeowners are concerned about how neighbors perceive exterior appearance (*ExtApp*), home solar WTP may be affected in either direction. A negative effect results if solar adversely affects architectural aesthetics, detracting from attractiveness. However, a direct effect on WTP is likely if HRS confers status to homeowners. By announcing support for the environmental investment, home solar offers neighborhood status incentives unavailable to GP participants[1].

Installation of HRS is a permanent conversion of a home to a clean, renewable part of the electric grid. The effect is long term because climate change impacts are greatest on future generations. If respondents with grandchildren or young children (*ChildGrnd*) display greater home solar WTP, this indicates concern for progeny and descendants and not simply concern future generations.

The last measure in the enhanced model is a number of residents (*Resid0-1* and *Resid4+*). More occupants of a home raise the energy consumption but also may increase the per capita energy efficiency. In seasonal homes common in beachside communities like the study area, benefits from solar may be lost. Thus, effect of these variables could be in either direction.

2.3. Combating sources of survey and value-elicitation bias. There are well-known sources of bias for this type of survey research. First, survey estimates are subject to bias if response rate is not equal across all population cohorts. Although higher overall response was encouraged by confidentiality assurance, this prevented follow-up surveys to contact nonrespondents. Instead, we addressed nonresponse bias via post-sample stratification. Census data and regional surveys of socioeconomic variables furnished benchmarks to quantify over- and under-sampling and obtain weights for variables distributed differently between returned questionnaires and the known population. Overall weights were used to generate weighted means and run weighted probit regression.

However, the survey design in this paper prevents two other causes of hypothetical survey bias: "yea

[1] Some utilities issue stickers for GP customers to post. Water utilities feared reclaimed would reduce property value. Instead, values rose in neighborhoods that posted reclaimed water irrigation "warnings" that announced their commitment to water conservation. Reclaimed water became a status symbol and its prices rose rapidly.

saying," where respondents tend to say what they think an interviewer wants to hear, and "warm glow," where respondents feel satisfaction from saying they want to help the environment (Menges, et al., 2005; Wiser et al., 2001). Neither of these types of bias are problems with our confidential, mail-in survey[1].

How representative were the responses? Respondents shared similar distributions with the local population for several variables surveyed: household income, age of housing stock, housing type, and length of stay in current residence. As expected, the sample was unrepresentative for two variables critical to the analysis, age and education. Fewer homeowners under 50 responded while too many seniors responded. Moreover, college degree holders were over twice as likely to respond as homeowners with less education. Oversampling of elderly is common in mail surveys, and high response by college graduates may result from their familiarity with environmental issues and a greater facility to complete the information-dense survey. Table 2 presents the weighted means.

Table 4. Weighted vs. unweighted means

	Weighted	Unweighted
Yes5+	22%	25%
Yes7+	10%	11%
Regressors		
Cost/Yr		$124
BuyEnvir	62%	67%
Envir'ist	34%	41%
RedOilDep	82%	86%
CutEmit	59%	63%
Age50-64	27%	33%
Age > 65	41%	50%
4YrColl	24%	59%
Inc35-69K	40%	37%
Inc > 70K	29%	39%
Move10+	50%	49%
Stay	87%	90%
Sqft < 1800	59%	54%
Sqft2800+	9%	12%
Built < 1970	33%	31%
Built1990+	30%	32%
Roof10+	21%	23%
RoofCat3	60%	63%
AC10+	23%	24%
Imprv < 10	45%	45%
Imprv20+	25%	30%
ExtApp	50%	56%
ChildGrnd	57%	59%
Resid0-1	25%	27%
Resid4+	11%	8%

Another class of survey bias is specifically associated with CV research. The study questionnaire used single-bounded dichotomous choice (SBDC), market-like scenarios to accept or reject a stated price. This is the preferred method in environmental surveys to elicit WTP if the cost to obtain a large sample is not a constraint[2]. SBDC most closely resembles market decisions and avoids problems such as outliers, high nonresponse, and anchoring encountered in bidding games, payment cards, and non-single-bounded valuation (Pearce et al., 2006).

A poorly designed CV study is likely to yield sizable upward bias in WTP estimates. Yet even SBDC value-elicitation surveys are subject to substantial bias. This bias occurs in hypothetical surveys because respondents may not answer WTP questions as seriously (Hanemann, 1994; Diamond and Hausman, 1994). Hypothetical bias is likely whenever affirmative answers do not commit respondents to make the payment (Byrnes et al., 1999; Rose et al., 2002). Hypothetical bias can be especially large when surveys ask about a proposed program that respondents may be attracted to but lack sufficient facts to make an informed choice (Loomis et al., 1996). Cummings et al. (1995), Blumenschein et al. (1998), and Champ et al. (1997) provide evidence of this bias in laboratory settings. Upward bias ranging from zero to 700 percent was confirmed in WTP field surveys as compared to actual participation rates in GP programs (Byrnes et al, 1999; Roe et al., 2001; Ethier et al., 2000; Champ and Bishop, 2001; Kotchen and Moore, 2007).

Methods to reduce or remove hypothetical bias are classified as ex ante and ex post (Whitehead and Cherry, 2007). Several studies employed combinations of ex ante and ex post techniques to mitigate the effects of hypothetical bias (Ethier et al., 2000; Champ and Bishop, 2001; Rose et al., 2002; Menges et al., 2005; Champ et al., 2005; Borchers et al., 2007).

Ex ante methods focus on creating a realistic market-like decision context for respondents. The goal of reality-based ex ante strategies is to elicit sincere, informed survey responses to the WTP with minimal bias by providing respondents with relevant information about (1) the environmental product in question, including facts not otherwise available without direct experience; (2) how much an affirmative WTP response to the survey would reduce their remaining budget for other desired products; and (3)

[1] Hypothetical bias also occurs if respondents try to "game" a survey by exaggerating WTP in hopes they can free ride it (Loomis et al., 1996). This bias is small for this local utility survey because most HRS support is from state and federal sources and NSB utility established solar hot water subsidies prior to conducting the survey.

[2] Other methods result in greater estimation efficiency because they obtain more information from each respondent.

available public or private substitutes capable of yielding equivalent environmental benefits. These three elements were incorporated into each version of the survey.

Ex post hypothetical upward bias, on the other hand, is common to any marketing survey not tied to a financial commitment. To correct for this response bias, we relied upon a follow-up inquiry of respondents who reply affirmatively to the WTP question (Champ and Bishop, 2001). These subjects were asked to rate their level of certainty about their decision on a scale of from 1 (very uncertain) to 10 (very certain). By recoding as "No" all of the less-certain affirmative WTP responses (certainty levels below 7 or 8), this ex post method has been found eliminates most hypothetical bias in GP studies (Whitehead and Cherry, 2007).

The certainty level distributions for home solar were similar but quite different from those for GP (Table 5)[1]. While the GP control group yields a median level of 7 just like that in the literature, hot water and PV solar have medians and modes at certainty level 5, reflecting lengthy financial commitment, complex information, and other considerations associated with choosing home solar. To accommodate inherently higher uncertainties, we assigned that a cutoff minimum of 5 for certainty-adjusted "Yes" WTP responses in the probit regressions.

Table 5. Distribution of "Yes" respondents to level of certainty follow-up question (level at which median located is boldfaced)

Level of certainty	Hot water	PV	Green pricing
1 – very uncertain	8%	11%	8%
2	6%	5%	3%
3	11%	11%	5%
4	9%	9%	7%
5	**29%**	**31%**	16%
6	12%	7%	7%
7	9%	9%	**10%**
8	6%	9%	15%
9	4%	3%	12%
10 – very certain	7%	5%	17%

3. Results

Prior to probit estimation, log likelihood ratio tests were needed to verify homogeneity of survey data and allow it to be pooled across the design cells. The first test found homogeneity could not be rejected (χ^2 = 14.40, p = .89, df =22) across solar hot water respondent data and solar PV respondents. Thus, probit could be run on the pooled data of all HRS respondents (Table 6, column 1). However, homogeneity was rejected (χ^2 = 40.82, p = .0087, df = 22) between solar survey data and green pricing data, so probit analysis of the GP control group data will be run seprately.

From the full sample column of Table 6, three of the four environmental resource attitude and behavior variables test significant with the expected positive sign. This result indicates that environmental factors do indeed influence WTP for renewables in a strong, multidimensional fashion. Moreover, the two upper-age dummies display the anticipated negative effects (relative to under-50), while tests of the higher-income variables confirm their expected direct effect. These findings are consistent with results from GP studies and establish that HRS responds to many of the same demand factors. However, the college education variable is not significant, and more disturbing still, neither is annual home solar cost.

Table 6a. Probit marginal effects of HRS from pooled data

	Full sample	*4YrColl* only	*4YrColl-BuyEnvir*
Constant	-0.504** (0.000)	-0.504** (0.000)	-0.404** (0.000)
Cost/Yr	-0.0008 (0.56)	-0.0004* (0.0499)	-0.0009** (0.003)
BuyEnvir	0.14** (0.000)	0.11** (0.007)	
RedOilDep	0.083* (0.03)	0.12* (0.02)	0.21** (0.004)
CutEmit	0.13** (0.000)	0.10* (0.011)	0.10 (0.06)
Envir'ist	-0.022 (0.48)	0.12** (0.004)	0.16** (0.000)
Age50-64	-0.093** (0.002)	-0.078 (0.06)	-0.079 (0.13)
Age65+	-0.19** (0.000)	-0.23** (0.000)	-0.29** (0.000)
4YrColl	0.051 (0.11)		
Inc35-69K	0.15** (0.000)	0.18* (0.03)	0.11 (0.23)
Inc > 70K	0.21** (0.000)	0.23** (0.002)	0.23** (0.007)
n	1181	737	518
Pseudo R^2	0.132	0.108	0.118

Notes: *p*-values are in parentheses. *, ** Significant at 5% and 1% level, respectively.

Table 6b. With inclusion of small and large PV dummies

	Full sample	*4YrColl* only	*4YrColl-BuyEnvir*
Constant	-0.498** (0.000)	-0.518** (0.000)	-0.426** (0.000)
Cost/Yr	0.0005** (0.009)	0.0004 (0.97)	-0.0009 (0.27)

[1] Confirmed by contingency test: χ^2 = 46.5 (p < .001, df =18), which rejects statistical independence among solar hot water, PV systems, and GP level of certainty distributions. However, χ^2= 6.72 (p = .67, df = 9), so cannot reject independence between solar hot water and PV distributions. Mean certainty level (6.5) is significantly higher among willing GP participants than among those willing to install HRS (5.1), with F = 13.9 for the ANOVA test.

Table 6b (cont.). With inclusion of small and large PV dummies

	Full sample	*4YrColl* only	*4YrColl-BuyEnvir*
BuyEnvir	0.14** (0.000)	0.11** (0.008)	
RedOilDep	0.086* (0.03)	0.13* (0.02)	0.21** (0.004)
CutEmit	0.13** (0.000)	0.10* (0.014)	0.10 (0.07)
Envir'ist	-0.025 (0.42)	0.11** (0.005)	0.16** (0.001)
Age50-64	-0.093** (0.002)	-0.083 (0.04)	-0.079 (0.13)
Age65+	-0.19** (0.000)	-0.23** (0.000)	-0.29** (0.000)
4YrColl	0.057 (0.07)		
Inc35-69K	0.15** (0.000)	0.19* (0.02)	0.12 (0.19)
Inc > 70K	0.21** (0.000)	0.24** (0.001)	0.24** (0.004)
Small PV	-0.072* (0.03)	-0.011 (0.81)	-0.028* (0.03)
Large PV	-0.18** (0.000)	-0.13** (0.006)	-0.15* (0.013)
n	1181	737	518
Pseudo R^2	0.145	0.117	0.128

Notes: *p*-values are in parentheses. *, ** Significant at 5% and 1% level, respectively.

First, notice that although most of the marginal effects for the full sample (Column 1 of Table 6a) are significant and with the expected sign, the annual net cost to an HRS adopter *Cost/Yr* is not significant although it has the expected negative sign. This apparent price insensitivity even becomes a direct relationship once rooftop system type (large or small PV vs. hot water) is controlled for in the full sample column of Table 6b.

However, the large marginal effect coefficients for attitude, behavior, income, and age variables indicate the existence of two distinct subpopulations, and that older, low-income, anti-environmental homeowners are unlikely to choose solar regardless of price. Thus, the price anomaly vanishes once analysis is restricted to the likely solar adopter subsample – college grads who buy environmentally-friendly products. Thus, both Tables 6a and 6b report the expected inverse and significant price response in Column 3.

Next, we assess the potential for the HRS program represented in the field survey to achieve financial viability while at the same time helping utilities meet their emission targets. The HRS costs in the Table 1 design were chosen to be comparable to those found to elicit substantial participation in the GP literature cited. Thus, as expected, those costs did in fact generate a substantial adoption rate of 22 percent (Table 4). The two critical assessment questions are (1) Will this adoption rate have much impact on utilities trying to reach their emission reduction targets? and (2) Is an HRS program with these participation costs financially valuable yet, and if not, when if ever will it be?

Can this HRS program take a sizable bite out of utility emissions? To do that, a substantial proportion of customers must install HRS and these adopters must, in turn, generate enough solar electricity to substantially reduce their demand for electricity generated by the utility. Based on New Smyrna Beach utility spreadsheets, two-thirds of electricity generated goes to residential customers, and owners of single-family, detached homes eligible for HRS adoption consume approximately 40% of residential usage. Applying the 22% adoption rate to installation of a 50-50 mixture of large and small PV systems, the result is a 3% reduction in utility greenhouse gas emissions. Considerably higher adoption rates could also be achieved once Florida approves third-party ownership to remove most adopter risks (Drury et al., 2012).

How about program viability? To assess that aspect, we calculated the present values for the program benefits of a large and small PV residential systems and compared that with the cost for those solar systems. The large PV system at the time of the survey was $35,000 (net of rebate and other subsidies) while the small system was $20,000. The cost to large PV system adopters averaged $225/year in the field survey and $150/year for the small PV system. However, those costs were presented as *net costs* to survey respondents, so the HRS program also receives all benefits from electricity they don't have to pay to generate. The large system reduces approximately two-thirds of utility demand while the small PV system cuts only about one-third.

Using a 25-year life for each system, an average monthly electric bill of $150, and a 5% discount rate, the combined present values of adopter annual costs and electricity saved is $20,600 for the large system and $10,800 for the small system, each well below the 2007-2008 system cost at the time of the survey. But utility rates have risen and PV systems prices have fallen dramatically and are expected to decline considerably before 2020 (Goodrich, 2012). So program viability may have a good chance in the near future.

As mentioned, Green Pricing WTP survey data could not be pooled with home solar data. This is not surprising considering how GP participation lacks the long-term consequences of a HRS decision. Nevertheless, the GP probit results for the same model (Table 7) serve as a control study for the preceding conclusions.

Table 7. Green pricing control group probit marginal effects by homeowners

	Yes7+	*Yes5+*
Constant	-0.688** (0.002)	-0.370** (0.03)
Cost/Yr	-0.0007* (0.012)	-0.0010** (0.005)
BuyEnvir	-0.083 (0.09)	-0.078 (0.14)
RedOilDep	0.11** (0.000)	0.050 (0.45)
CutEmit	0.13 (0.052)	0.17** (0.001)
Envir'ist	0.053 (0.13)	0.103* (0.03)
Age50-64	-0.003 (0.95)	0.016 (0.77)
Age65+	-0.023** (0.56)	-0.090 (0.08)
4YrColl	0.10* (0.03)	0.11 (0.053)
Inc35-69K	-0.035 (0.35)	-0.13 (0.81)
Inc > 70K	0.021** (0.64)	0.071 (0.25)
n	381	381
Pseudo R^2	0.168	0.171

Notes: *p*-values are in parentheses. *, ** Significant at 5% and 1% level, respectively.

Suppose the GP probit regression results were not consistent with those in the GP literature. Then it could be contended that the home solar findings in Table 6 are the result of an atypical study area, methodology or survey design. However, the GP literature results are consistent with those of our control group data for the *Yes7+* certainty level (used in GP studies) as well as for the *Yes5+* level (appropriate for HRS decisions). In particular, the negative effect of annual program cost is significant in the GP probit regressions – in contrast to the corresponding test for the full sample in Table 6.

Table 8. Corrections to sampling error bias probit marginal effects for home solar

	Weighted	Unweighted
Constant	-0.504** (0.000)	-0.528** (0.000)
Cost/Yr	-0.00008 (0.56)	-0.0002 (0.36)
BuyEnvir	0.083** (0.000)	0.110** (0.001)
RedOilDep	0.022* (0.03)	0.076 (0.13)
CutEmit	0.13 (0.48)	0.054 (0.104)
Envir'ist	0.093** (0.000)	0.127** (0.002)
Age50-64	-0.19** (0.002)	-0.068 (0.08)
Age65+	-0.051** (0.000)	-0.19** (0.000)
4YrColl	0.15 (0.11)	0.067* (0.046)
Inc35-69K	0.21** (0.000)	0.14** (0.006)
Inc > 70K	0.14** (0.000)	0.17** (0.000)
n	1181	737
Pseudo R^2	0.132	0.108

Notes: *p*-values are in parentheses. *, ** Significant at 5% and 1% level, respectively.

Weighted probit regression was reported in the Tables 6 and 7. The previous section described how these weights were derived from Census and area survey demographic baselines to correct for any nonresponse bias in the survey sample. Table 8 compares the unweighted probit alongside the weighted from Table 6 so that the bias effects may be examined. The similarity of the two columns suggests that nonresponse bias has limited impact on such studies.

Table 9. Marginal effects for home solar in standard vs. enhanced models

Base model		Model with resident tenure, house and roof condition, household size, aesthetics, progeny			
Constant	-0.504** (0.000)	*Constant*	-0.560** (0.000)	*Sqft < 1800*	0.021 (0.59)
Cost/Yr	-0.00008 (0.56)	*Cost/Yr*	-0.00010 (0.51)	*Sqft2800+*	0.059 (0.33)
BuyEnvir	0.083** (0.000)	*BuyEnvir*	0.143** (0.000)	*Built < 1970*	0.020 (0.62)
RedOilDep	0.022* (0.03)	*RedOilDep*	0.122** (0.006)	*Built1990+*	0.021 (0.64)
Envir'ist	0.13 (0.48)	*Envir'ist*	-0.037 (0.28)	*Roof10+*	0.020 (0.63)
CutEmit	0.093** (0.000)	*CutEmit*	0.169** (0.000)	*RoofCat3*	-0.042 (0.21)
Age50-64	-0.19** (0.002)	*Age50-64*	-0.062 (0.10)	*AC10+*	-0.008 (0.84)
Age65+	-0.051** (0.000)	*Age65+*	-0.167** (0.000)	*Imprv < 10*	-0.019 (0.63)
4YrColl	0.15 (0.11)	*4YrColl*	0.079* (0.03)	*Imprv20+*	-0.037 (0.37)

Table 9 (cont.). Marginal effects for home solar in standard vs. enhanced models

Base model		Model with resident tenure, house and roof condition, household size, aesthetics, progeny			
Inc35-69K	0.21** (0.000)	*Inc35-69K*	0.11* (0.02)	*ExtApp*	-0.008 (0.79)
Inc > 70K	0.14** (0.000)	*Inc>70K*	0.17** (0.001)	*ChildGrnd*	-0.056 (0.10)
		Move10+	0.019 (0.61)	*Resid0-1*	-0.14** (0.000)
		Stay	-0.090 (0.09)	*Resid4+*	-0.004 (0.94)
n	1181			*n*	963
Pseudo R^2	0.132			Pseudo R^2	0.154

Notes: *p*-values are in parentheses. *, ** Significant at 5% and 1% level, respectively.

Is there any effect of the 15 additional variables (described in section 2) on the homeowner decision to install HRS? Table 9 shows that with one exception, these variables do not test significant nor do their presence indicate underspecification of the original model. In particular, participation cost is still not significant. The only added variable testing significant in the enhanced model is *Resid0-1*, with its negative effect likely due to the low return on solar for seasonal residents.

Conclusions and policy implications

HRS policy is viable due to the advent of net metering, rapidly declining PV systems costs (Goodrich et al., 2012), and innovative third-party ownership in owner-sited PV systems that removes most of the homeowner's financial and technological risks (Drury et al., 2012). Moreover, states like Florida are falling short of their utility emission targets. This study responds to these new needs for HRS policy analysis by conducting a field survey that overcomes the modeling and methodological barriers that have long discouraged such research.

By drawing upon the extensive environmental survey literature and adapting a GP model to home solar, this paper confirmed that the WTP premium for HRS is directly related to income, education, and support for environmental attitudes and actions and inversely related to age. These results are consistent with the GP literature. Moreover, there is little evidence that the traditional CV model is underspecified when applied to unique considerations homeowners confront in deciding about HRS. Financial and lifestyle proxy variables – such as home reinvestment behavior, structural condition, aesthetic concerns, and mobility – did not test significant nor did they improve the fit or indicate bias.

However, the price relationship seems more complex and nuanced for HRS adoptions than the clear-cut inverse price relationship displayed in GP programs. In particular, WTP displays significant inverse relationship only within the college-educated subpopulation, especially when combined with behavior preferences toward green shopping.

We also examined the overall weighted adoption rate to assess program viability and impact on utility emissions reduction goals. Although HRS programs may be limited to a modest 3 percent impact currently, future expansion of the program to more risk-averse customers and non-owner-occupied structures could have great potential. We also determined that the HRS program at the costs quoted in the field survey would not have been viable at the time. However, evidence of rapid price declines in system costs could result in program viability in the foreseeable future.

Policymakers considering these findings should be aware of three limitations. First, although they may be applicable to Sunbelt regions with similar demographics, regions with different socioeconomic characteristics and housing should consider adapting the survey design. Secondly, this research is a snapshot of evolving environmental and energy attitudes, so the findings are only transitional benchmarks needing periodic re-estimation of shifting WTPs. As homeowners become knowledgeable and comfortable with HRS by observing neighborhood installations, respondents will be able to process solar WTP questions without need of lengthy survey narratives.

A final caution is that home solar should occupy only one segment of any well-designed renewable energy and conservation policy within a portfolio of options based on relative costs and WTP preferences. Other renewables such as wind is lower cost in many regions, conservation is cost-effective, and some homeowners will opt for non-invasive GP commitment instead.

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